This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Congressional serial set

United States. Government Printing Office

6228

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETINS

Nos. 497-500

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

181613

CONTENTS

Geological Survey bulletin 497; Reconnaissance of Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nev.
Same 498; **Headwater** regions of Gulkana and Susitna rivers, Alaska.
Same 499; **Coal near** Black Hills, Wyoming-South Dakota.
Same 500; **Geology** and coal fields of lower Matanuska Valley, Alaska.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 497

A RECONNAISSANCE
OF THE
JARBIDGE, CONTACT, AND ELK MOUNTAIN MINING DISTRICTS

ELKO COUNTY, NEVADA

BY

F. C. SCHRADER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

CONTENTS.

Page.
Introduction 9
The Jarbidge district 11
  Location 11
  Previous descriptions 13
  Climate 13
  Vegetation 14
  History and present conditions 14
  Physical features 19
    Great Basin province 19
    Snake River valley province 19
    Jarbidge Mountains 21
  Geology 27
    Sedimentary rocks 27
      Paleozoic sedimentary rocks 27
      Tertiary sedimentary rocks 31
      Quaternary deposits 32
        Glacial deposits 32
        Snowslide deposits 32
        Talus deposits 33
        Alluvial deposits 33
    Igneous rocks 33
      Intrusive granitic rocks (Cretaceous?) 33
      Tertiary volcanic rocks 35
        General features 35
        Old rhyolites (Miocene?) 36
          Occurrence and distribution 36
          Structure 37
          Macroscopic character 38
          Microscopic character 39
          Chemical composition 40
        Young rhyolites (Pliocene?) 42
          Occurrence and distribution 42
          Macroscopic character 44
          Microscopic character 44
        Age of the volcanic rocks 46
  Mineral deposits 47
    Early deposits (Cretaceous?) 47
    Late deposits (post-Miocene) 48
      Occurrence and distribution 48
      West system 50
      East system 51
      Cross system 52
      Structure and composition of the veins 52
      Occurrence of the gold 57
    Origin of the veins 58
    Alteration of wall rock 64

The Jarbidge district—Continued.

Page.
- Description of properties 66
  - Properties on the west system of veins 66
    - Pavlak mine 67
      - Location 67
      - Geology 67
      - Veins and ore 67
      - Developments and production 68
      - 4-M lease 68
      - Riddle lease 69
      - Pavlak lease 70
      - Ham-And or Curley lease 71
    - Pan property 72
    - Sunflower group 72
    - Red Bird and Duffy claims 72
    - Bourne mine 73
      - Location 73
      - Developments 73
      - Geology 73
      - Veins and ores 74
    - Missmo group 76
    - Buster mine 76
    - Pick and Shovel mine 77
    - Bluster mine 80
    - Success group 82
    - Rock Creek Fraction and It claims 82
    - Josephine group 82
    - Good Luck property 82
    - St. Joe group 83
    - Free Gold group 83
    - Ozark group 84
      - Location 84
      - Geology 84
      - Ore deposits 84
    - Mammoth claim 86
    - Guess group 86
    - Vulcan group 87
    - Mahogany mine 87
    - Amazon-Rainbow group 87
  - Properties of the East or Crater group 88
    - Location and general character 88
    - Second Crater 89
      - Van Alder mine 89
      - Howard-McCoy mine 91
      - Victoria group 92
      - Cœur d'Alene-Jarbidge property 92
    - Third Crater 92
      - Arkansas property 92
      - True Fissure group 93
      - Snowslide Gulch 93
    - Fourth Crater 93
      - Sugar group 94
      - Round Up group 94
      - White Quartz vein 94

The Jarbidge district—Continued.

Description of properties—Continued.

Page.
Properties of the East or Crater group—Continued.
Fifth Crater ---- 94
First or Jack Crater ---- 94
Jack Creek area ---- 95
Other areas and prospects ---- 96
Placer deposits ---- 97
The Contact district ---- 99
Geography ---- 99
Location ---- 99
Topography and drainage ---- 99
Climate ---- 101
Vegetation ---- 102
History and present conditions ---- 102
Geology ---- 104
Sedimentary rocks ---- 104
Paleozoic rocks ---- 104
Tertiary lake beds ---- 106
Igneous rocks ---- 107
Intrusive granite rocks (Cretaceous?) ---- 107
Tertiary volcanic rocks ---- 108
Dike rocks ---- 109
Classes and general features ---- 109
Syenitic or siliceous dikes ---- 110
Lamprophyric or basic dikes ---- 111
Summary of geologic history ---- 112
Mineral deposits ---- 112
Location and general character ---- 112
Contact-metamorphic deposits ---- 114
Fissure-vein deposits ---- 115
Replacement deposits ---- 116
Detailed descriptions of mines and prospects ---- 117
Ellen D. Mountain area ---- 117
Brooklyn mine ---- 117
Allen and Delano claims ---- 119
Empire mine ---- 119
Palo Alto mine ---- 120
Blue Bird mine ---- 121
Delano and Copper King claims ---- 121
Antelope mine ---- 122
Queen of the Hills prospect ---- 123
Rattler prospect ---- 124
Mammoth and neighboring prospects ---- 124
Bonanza mine ---- 126
Ivy Wilson group ---- 129
Copper Shield and neighboring groups ---- 132
Florence group ---- 132
Copper Shield group ---- 133
Salt Lake group ---- 133
Yellow Girl mine ---- 134
Hickey prospect ---- 134

The Contact district—Continued.

Detailed descriptions of mines and prospects—Continued.

Page.

- China Mountain area 134
  - Location and general features 134
  - Chinaman mine 136
  - War Eagle mine 136
  - Turo-Sheckles mine 137
  - Turo mine 138
  - High Ore mine 138
  - Camp Bird prospect 138
- Blanchard Mountain area 139
  - Location and general features 139
  - Zetta Blanchard group 140
  - Johnson group 141
  - R. O. C. prospect 142
  - Hice mine 143
  - Kratz mine 145
- Middle Stack Mountain and Trout Creek area 146
  - Location and general features 146
  - O'Connell group 146
  - Clark group 147
  - Boston mine 149
  - Toano group 150

The Elk Mountain district 151
- Geography 151
  - Location 151
  - Topography 151
- Geology 152
- Mineral deposits 154
  - General features 154
  - Austeon tunnels prospect 155
  - O'Neil prospect 156
  - Red Elephant incline 156
  - Gold prospect 156
  - Estes prospect 157
  - Other prospects 157

Index 159

ILLUSTRATIONS.

Page.

PLATE I. General geologic map showing relative position of the Jarbidge, Contact, and Elk Mountain mining districts, Nevada 10

II. Geologic reconnaissance map and section of the Jarbidge mining district, Elko County, Nevada 12

III. *A*, Jarbidge, Jarbidge River valley, and mountains in old rhyolite, looking S. 10° W.; *B*, South Branch valley at head of Jarbidge River 16

IV. Jarbidge Mountains, looking southeast 16

V. *A*, Part of rim of First Crater; *B*, Van Alder and Howard-McCoy mines, in Second Crater 24

VI. *A*, Pine Creek valley, in old rhyolite; *B*, Old rhyolites near head of Jarbidge River 24

VII. *A*, Buster vein outcrops; *B*, Pick and Shovel mine and outcrops of Pick and Shovel vein 50

VIII. Pseudomorphic quartz and adularia after calcite 54

IX. Photomicrograph of pseudomorphic quartz and adularia after calcite 56

X. Photomicrograph of gold ore 60

XI. *A*, Gold ore, "blistery" phase; *B*, Gold ore, nodular or kidney phase 62

XII. Map of the principal surveyed claims in the Jarbidge district 66

XIII. Map of part of surveyed and unsurveyed claims in the Jarbidge district 66

XIV. Geologic reconnaissance map and sections of Contact district, Nevada 100

XV. *A*, Palo Alto mine and Middle Stack Mountain, from Delano Hill; *B*, View showing topography of granodiorite bowldery surface in Thompson Gulch 100

XVI. *A*, Topography in eroded Paleozoic sedimentary rock belt, China Mountain area; *B*, Lake beds of tuffaceous sandstone (Humboldt formation, Pliocene) in Knoll Creek valley 100

XVII. View of Contact (new town), looking west-northwest 102

XVIII. *A*, View of Old Contact, looking N. 75° E.; *B*, Characteristic sedentary bowlders produced by weathering of the granodiorite in the Contact mining district 102

XIX. Map showing distribution of principal mineral claims in western part of the Contact mining district, Nevada 112

XX. Map showing principal claims in the southeastern or China Mountain portion of the Contact mining district, Nevada 112

Page.
PLATE XXI. Map showing approximate location of principal claims in northeast or Middle Stack Mountain portion of the Contact mining district, Nevada 112
XXII. Map showing approximate distribution of the principal veins, mineral-bearing dikes, and deposits in the western part of the Contact mining district, Nevada 112
XXIII. *A*, Ore-bearing syenite dike cutting granodiorite on Portland ground; *B*, Brooklyn mine 118
XXIV. *A*, New York vein outcrops and openings; *B*, Bonanza mine and camp, in Bonanza Gulch 126
XXV. *A*, East prong of Elk Mountain mineral-bearing horseshoe; *B*, Mammoth vein in cut and ore 152
XXVI. View of Elk Mountain 152
FIGURE 1. Index map showing location of the Jarbidge district 12
2. Diagram showing trend and relative position of the principal veins in the Jarbidge district 49
3. Sketch of normal fault structure at Van Alder mine 90

A RECONNAISSANCE OF THE JARBIDGE, CONTACT, AND ELK MOUNTAIN MINING DISTRICTS, ELKO COUNTY, NEVADA.

By F. C. Schrader.

INTRODUCTION.

This report is based on 27 days' field work in July and August, 1910, of which 14 days were given to the Jarbidge district, 12 to the Contact district, and about half a day to the Elk Mountain district. During this period the mines and more important prospects were hurriedly visited and located by compass and aneroid traverses.

As the districts had never been surveyed or mapped, control in the Jarbidge district was obtained by measuring with steel tape a base line about three-fourths of a mile in length, on the open ridge west of Deer Creek, about 1½ miles northwest of Jarbidge. From stations established at the ends of this base a system of triangulation, indispensable in so rugged a country, was begun and carried on throughout the work concurrently with the contour and other sketching, and tied to Government township and section corner monuments of the ninth standard parallel, found later in the southern part of the field.

Both vertical-angle and aneroid readings were employed in determining elevations, but the elevations as a whole rest on aneroid readings carried into the district from Twin Falls, Idaho, a distance of 95 miles, two days being required to make the trip.

The topographic map of the Jarbidge district (the base of Pl. II), which covers an area of almost 170 square miles, was made by R. D. Pickett, working independently, with plane-table and telescopic alidade. The topographic map of the Contact district (the base of Pl. XIV), which covers an area of about 450 square miles, was made by Nelson W. Sweetser.

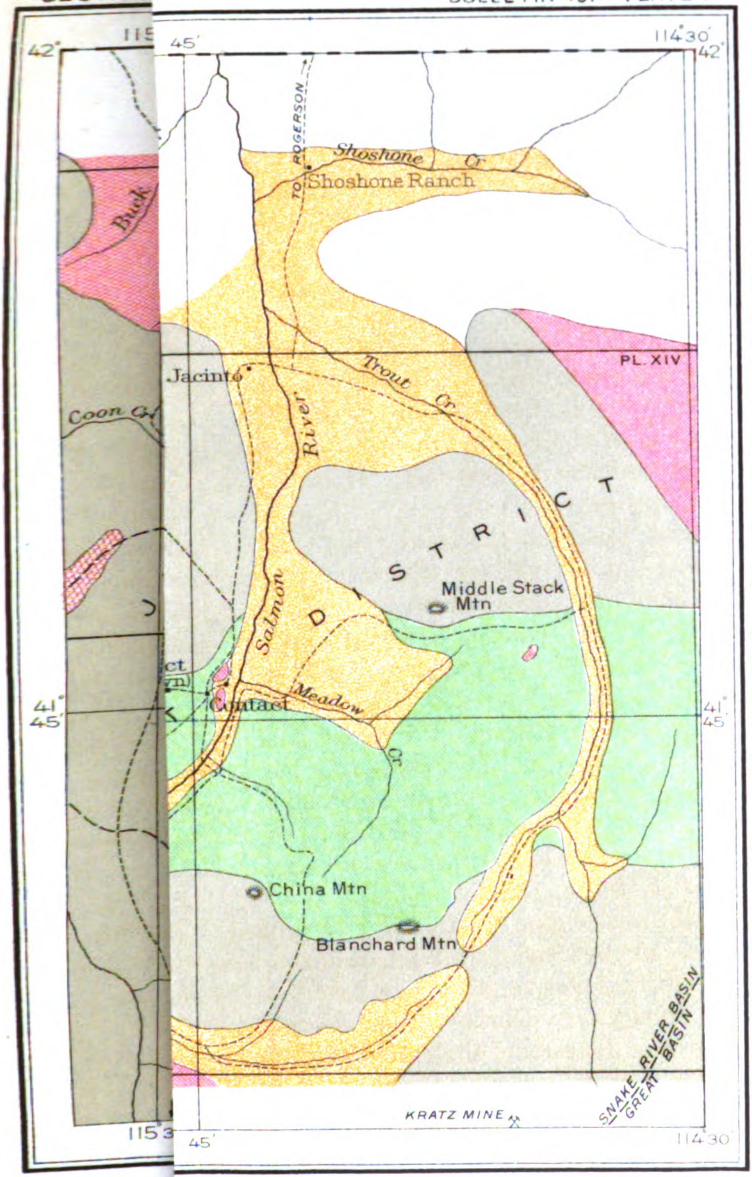
Thanks are due to the several companies, mining men, operators, the forest ranger, and prospectors for valuable information and assistance generously extended in all the districts; to Mr. Waldemar Lindgren, in charge of the metalliferous work of the Geological

Survey, and to Messrs. F. L. Ransome, J. B. Umpleby, and other members of the Survey for criticisms and petrographic assistance in the preparation of the report; and to Messrs. George Steiger and W. T. Schaller for chemical analyses and tests of the rock and ore specimens.

The area comprising the Jarbidge, Contact, and Elk Mountain districts (see index map, fig. 1, and general geologic map, Pl. I), lies in Elko County, in the northeastern part of Nevada. It is a rectangular area between 41° 37′ north latitude on the south and 42°, or the Idaho State line, on the north, and between 114° 30′ and 115° 30′ west longitude. On the east it extends within 25 miles of the Utah State line. It is about 35 miles long and 26 miles wide and covers about 1,400 square miles. The area lies in the northeastern part of the region known as the Nevada Plateau, at a general elevation of about 6,000 feet. It inclines gently to the east and is for the most part treeless.

Like the Great Basin on the south, this area is characterized by numerous broad, infilled valleys separating higher portions of the plateau and mountain ranges, which in parts are high and rugged. The main valleys lie at elevations of about 5,400 feet and above them the highest mountains rise to elevations of nearly 11,000 feet. Where watered the valleys are fertile. The area contains parts of two grand features of this western country—the Great Basin on the south and the Snake River valley on the north—and the intervening divide crosses its southern corners, as shown on Plate I. It lies mainly in the southern part of the Snake River basin, on the headwaters of Salmon and Bruneau rivers, which are among the strongest south-side tributaries of the Snake.

The area lies in a region of folded and eroded Paleozoic sedimentary rocks intruded by granitic batholithic masses and dikes, flooded by Tertiary lavas, and in part overlain by Tertiary lake sediments and Quaternary débris. The Paleozoic rocks consist principally of quartzite, limestone, shale, and slate and seem to be Carboniferous. The granitic intrusive rocks are principally granodiorite and are probably of Cretaceous age. The Tertiary lavas are principally rhyolite.



GEN TAIN MINING DISTRICTS, NEVADA

A HOEN & CO LI

Note: Rectangles represent areas of Jarbidge and Contact districts as shown on Plates II and XIV

▨ Tertiary lake b
gravels and a
some v

▨ Paleozoic sedimentary rocks

× Prospect

THE JARBIDGE DISTRICT.

LOCATION.

The Jarbidge district lies in the northern part of Elko County, in northeastern Nevada, near the Idaho State line on the north and about 60 miles from the Utah State line on the east, as shown in figure 1 and Plate I. It is comprised within an area about 14 miles square, extending west of the main Jarbidge River and east of the East Fork. The district lies in the rugged mountains between 5,500 and 11,000 feet in elevation, on the upper north slope of the high east-west range that forms the divide between the Great Basin on the south and the Snake River valley on the north. To this range, or portions of it, particularly to the southwest of the Jarbidge district, the name Bruneau Range or Bruneau Mountains has been applied. Jarbidge, the camp (shown in Pl. III, *A*), is located near the middle of the western half of T. 46 N., R. 58 E., on Jarbidge River, at an elevation of about 6,200 feet.

The General Land Office map of Nevada shows an unsurveyed area about 20 miles square about 20 miles east of the Duck Valley Indian Reservation. This is the only large area in this part of the State that has not yet been subdivided. It extends from the Idaho State line southward across the divide, where, on the Great Basin side, it includes a considerable portion of the Marys River drainage basin, and from the west fork of Bruneau River on the west beyond the east fork on the east. The Jarbidge district lies in the heart of this area and so far as indications of mineral-bearing rocks are concerned might roughly be regarded as coextensive with it. The district is 15 miles from Mountain City, 20 miles from Edgemont, and 25 miles from Tuscarora, all three points being located west or southwest from Jarbidge, in Nevada. It is 100 miles southeast of the Silver City-De Lamar district, Idaho.

The nearest railway points in air line are Rogerson, Idaho, 50 miles to the north, on a spur of the Minidoka & Southwestern branch of the Oregon Short Line, and Deeth, Nev., 55 miles to the south, on the Southern Pacific and Western Pacific railways. Elko, the county seat, is 70 miles distant, on the Southern Pacific. At present the center of the district is near latitude 41° 50′ north and longitude 15° 25′ west.

The term "Jarbidge" is said to come from the Indian name "Ja-ha-bich," meaning the devil. Traditionally it is applied to this district from Indian association of diabolic power with the cataclysmic

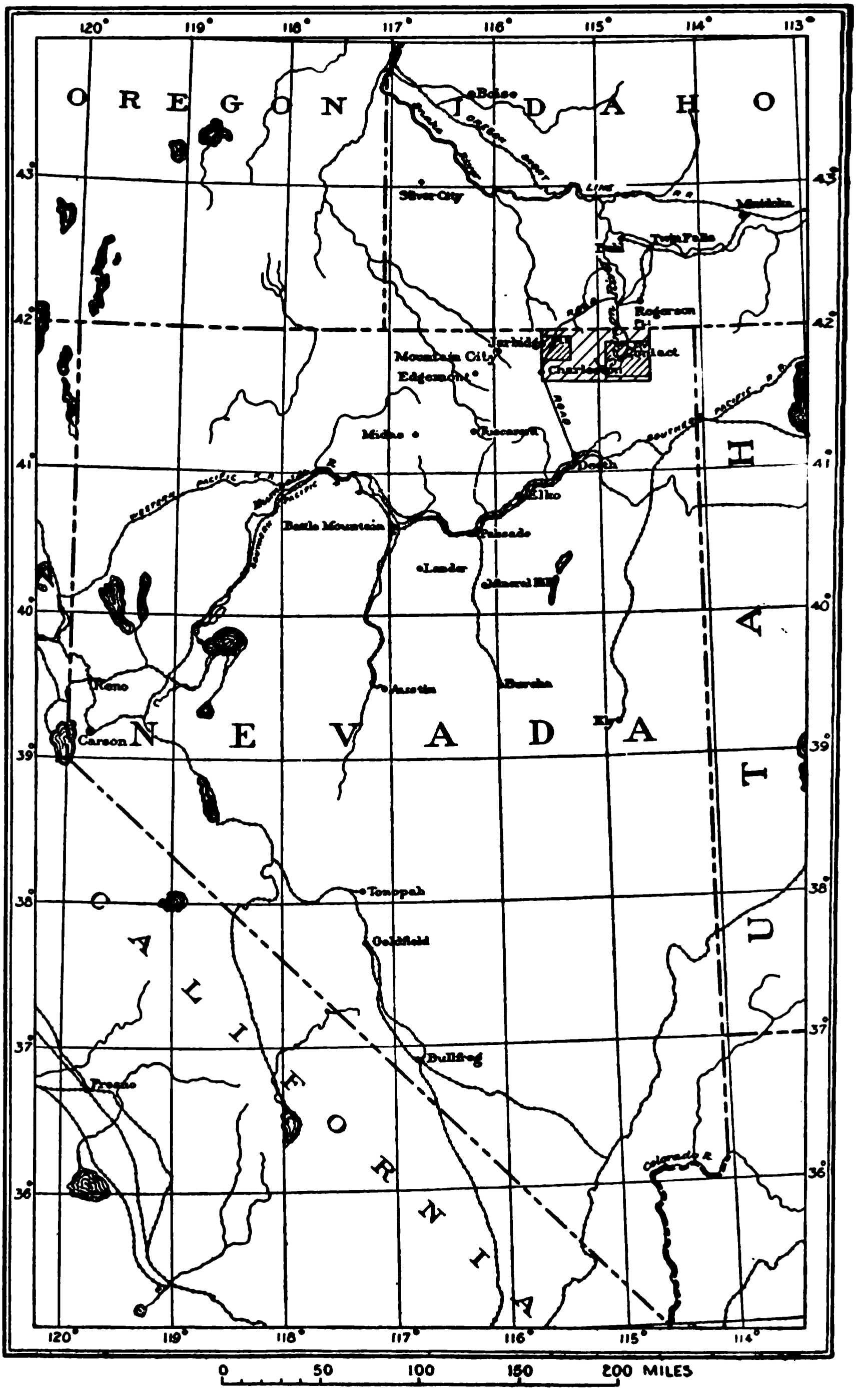
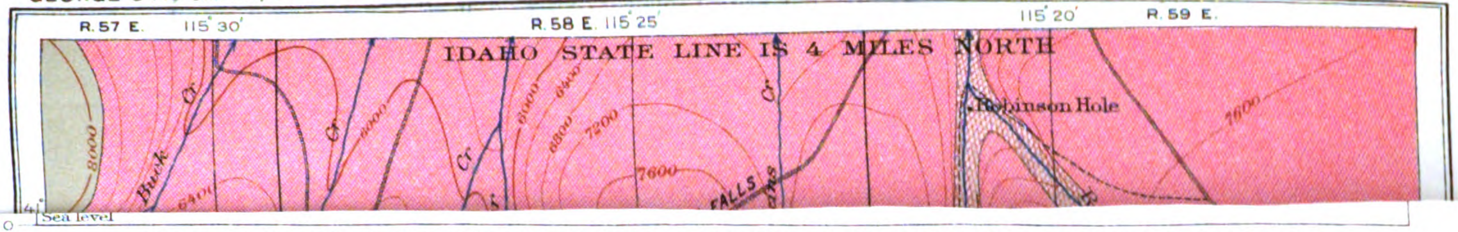
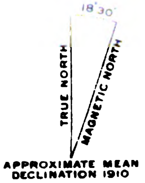


Figure 1.—Index map showing location of the Jarbidge district.

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 497 PLATE II





GEOLOGIC RECONNAISSANCE MAP AND SECTION OF THE JARBIDGE MINING DISTRICT, ELKO COUNTY, NEVADA

Scale $\frac{1}{125000}$

1 0 1 2 3 4 5 Miles

Contour interval 400 feet

1912

LEGEND

TERTIARY

Pliocene (?)

☐ Younger or rim-rock rhyolite

☐ Intervolcanic rhyolite dikes

Miocene (?)

☐ Older (ore bearing) rhyolite

CRETACEOUS (?)

☐ Granodiorite dikes and sheets, granular intrusives

🟩 Granodiorite and allied granular intrusives, principally stocks and dikes

PALEOZOIC

🟫 Principally Paleozoic sedimentary rocks quartzites, limestones, and shales, with granitic intrusives, notably granodiorite

⚒ Mine

× Prospect

○ Section corner

— Fault

△ U. S. Location Monument

volcanism suggested by the rugged mountains, high peaks, deep canyons, and hot springs of the region, and probably also from local eruptions of lavas which the Indians may have witnessed in the adjoining Snake River valley within the last century, the eruptions being regarded as manifestations of the evil spirit and the lavas perhaps being correlated in origin with similar ones exposed in the Jarbidge Mountains.

PREVIOUS DESCRIPTIONS.

So far as its geology and mineral deposits are concerned the district was discovered only about a year ago, previously being practically unexplored. The literature bearing directly on the district consists of short papers appearing in current mining journals, mainly for the year 1910, describing the conditions and development of the district, the mines, the camp, the prospects, and the new discoveries. Papers by W. A. Scott and by Nelson W. Sweetser appeared in the Mining and Scientific Press of April 30 and of December 31, but a number of short articles by Winthrop W. Fiske, mining engineer, of Jarbidge, have helped more than anything else to make the district known to the mining world and the public. Most of Mr. Fiske's papers have appeared in the publications named below, under some such heading as "Jarbidge, Nevada."

Salt Lake Mining Review: January 30, February 15, 28, March 30, June 15, July 30, September 30, November 15, 30, 1910, February 15, 1911.
Mining and Scientific Press: April 30, June 18, 25, September 3, 1910.
Mining World: October 1, 8, December 24, 31, 1910.
Engineering and Mining Journal: October 15, 1910.

CLIMATE.

The district lies between the desert region of the Great Basin on the south and that of the Snake River valley on the north, so that its climate, particularly in summer, partakes in large measure of that of these regions, being modified, of course, by the greater elevations. The summers are long and dry and there is great daily range between day and night temperatures. The nights are usually cool or cold, with frosts late in spring and early in autumn, and the days are warm with abundant sunshine, but owing to the dryness of the air the heat is not oppressive. The climate is similar to that of Silver City, Idaho.

The precipitation occurs mostly in winter and falls mainly as snow, which in the higher mountains accumulates to considerable depths, lasting in places throughout the summer. Springs feed perennial streams by which the district is well supplied with wholesome water.

According to Winthrop W. Fiske,[1] in 1909 snow began to remain on the mountain tops early in October and in the valleys late in

---

[1] Private letters of Dec. 10, 1910, and later date.

November. In 1910 snow did not begin to remain on the mountain tops until after the middle of October, and up to December 10, although considerable snow fell at times in the valley at Jarbidge, it was usually removed in a day or two by rain. Toward the later part of December winter seemed to set in for good, and by January 2, 1911, snow lay 10 inches deep in the valley at Jarbidge and several feet deep on the mountains.

In winter the temperature rarely falls below 20° F. The coldest weather in the winter of 1909–10 was on or about January 10, when the temperature reached 12° below zero. During the winter of 1910–11 the coldest day reported up to January 9 was January 2, when the mercury fell to 8° below zero.

VEGETATION.

The area lies in the Humboldt National Forest and contains considerable timber along the larger streams and at the heads of the valleys, as is shown in Plate III, *B*. According to the Forest Service,[1] the principal commercial trees are nut pine, or limber pine (*Pinus flexilis*), alpine fir (*Abies lasiocarpa*), aspen (*Populus tremuloides*), and mountain mahogany (*Cercocarpus ledifolius*). The better stands occur on the east and north slopes. Of these trees the pine is the only one suitable for lumber. Much of the timber, however, is suitable for use in mining. The area contains many trees about 2 feet in diameter and is now supplying frame timbers for the large Pavlak mill. Along the streams there are groves of cottonwood and willow. There is also considerable small timber, much of which, however, has been fire killed by the sheepmen, who, in grazing the country for many years past, were wont to burn off the slopes to improve the range. Mountain mahogany, juniper, and aspen, mostly trees of small or stunted growth, are plentiful and widely distributed and extend high up the mountain slopes, as shown in Plate IV.

Favorable slopes from the foothills to the top of the mountains are clothed with a fair growth of good forage grass (as shown in the foreground in Pl. IV), which renders the country a summer range for stock and sheep. During the last season large bands of sheep were grazing in the vicinity of Jarbidge.

HISTORY AND PRESENT CONDITIONS.

The history of the Jarbidge mining district scarcely begins before 1909. Jack Sinclair, an old-time prospector from Silver City, is reported to have visited the region in the late sixties. Excavations that were regarded as traces of old workings were found in the eastern part of the district, on East Fork of Jarbidge River, as early as 1880, by the Wilkins brothers, whose large horse range on the Idaho side included the East Fork country. The stockmen paid little attention to mineral deposits. The first ore discovered in the district is reported to have been found on East Fork about 1904 by one Vishim, a sheep tender and former placer miner, who in looking for a sheep range came across some of these old workings, from which he brought out a piece of quartz that assayed $1,200 or more to the ton in gold. So far as learned, however, this find was not followed by any effort to exploit or work the ground. In 1907 C. M. Howard, a stockman having a ranch in the northeastern part of the district, prospected the present Bourne ledge, on Jarbidge River, but found only low-grade ores and staked no claims.

---

[1] H. E. Fenn, acting district forester, in official letter of Dec. 28, 1910.

The discovery that led to the founding of the present camp and district was made by D. A. Bourne in 1909. Starting in the foothill mesa country in the vicinity of the State line, about 9 miles from the present site of Jarbidge, in 1908, he slowly ascended Jarbidge River, prospecting and panning the gravels of the river and tributaries. Having finally, late in the autumn of 1909, obtained his best prospect at the mouth of the tributary that now bears his name, he ascended this stream for about half a mile and worked for some time on the bold ledge that outcrops at this point on its north bank, obtaining by panning and sluicing the moderate return of $7 or $8 a ton. A little later, in company with friends, he discovered and located the adjoining higher ground on the south, where bolder outcrops marking the site of the present Bourne mine look down upon the scene of his former humble operations.

At about the same time the Pavlak and Buster groups, almost adjoining the Bourne and extending down to the river on the southwest, and the Pick and Shovel, high up on the mountain side to the southeast, were located and opened with good results, ore of shipping grade being found within 10 feet of the surface.

The Pick and Shovel ledge was discovered independently by John Escalon, a lone prospector, who, with pack on his back, entered the district from Charleston on the south. When, on descending the Jarbidge Valley, which he supposed to be virgin ground, he encountered Bourne, Pavlak, and other prospectors there preparing for mining operations, he hastened back to stake the Pick and Shovel ledge, whose rich float he had observed on the steep mountain side the day before.

Reports of these discoveries were soon spread abroad, and by October about 50 men had arrived in camp, most of whom spent the winter there. A meeting was called, the Jarbidge mining district was organized, and a recorder was elected. On December 10, 1909, with but 16 men present, a purse of $50 was raised to have the first mail brought in.

Early in 1910 the Bluster, Bunker Hill, Ozark, and other groups were located and prospected, with good results. In February or early March, 1910, certain newspapers published a statement that the

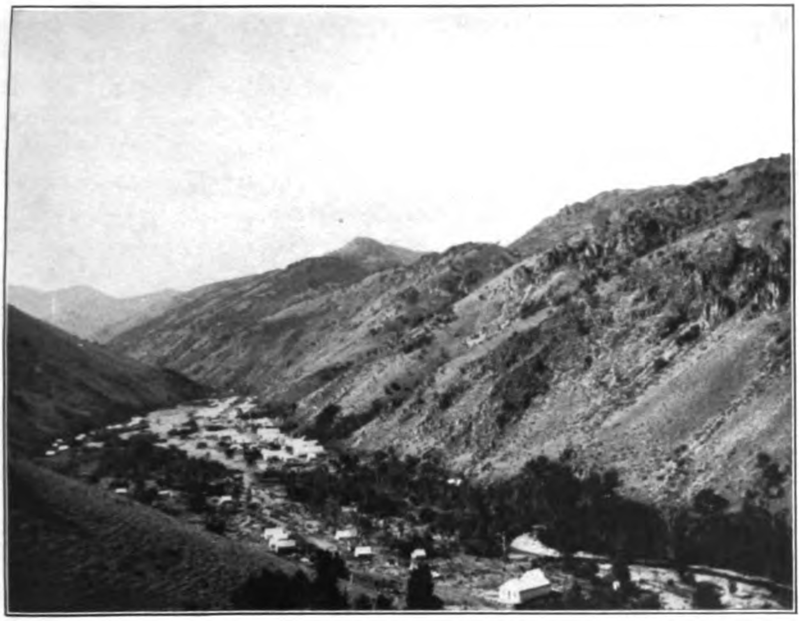
Bourne mine had over $27,000,000 worth of gold ore in sight. This announcement led to a stampede for the district, as a result of which the population of the camp was swelled to 1,500 during late March and early April. A city of 500 tents, erected on the present site of Jarbidge (Pl. III, *A*) and extending for 3 miles along the river bank, sprang up, and although the ground was heavily covered with snow—in places 15 or 20 feet deep—almost the entire country was quickly "staked" on snowshoes without being prospected. By the middle of April over 500 claims had been staked and filed for record in the district.

This movement, considering the various callings represented by its participants, the many and widely separated sections of the country from which they so quickly came, the inclemency of the season, and the conditions of travel, was remarkable, for there were no established lines of transportation and no wagon road within 12 miles of the camp, and after leaving the nearest railroad station, Twin Falls or Buhl, in southern Idaho, these men were compelled to travel a distance of 95 miles, mostly over the Snake River lava plain. The last 12 miles of this journey, from the Wilkins Hot Springs ranch (also called Rimrock), on East Fork, about a mile from the State line on the Idaho side, had to be traversed through deep mud, slush, and snow, on horseback or afoot, with baggage and freight packed on the backs of animals or men. A horse, too, was then considered a luxury and was hard to get at any price.

It is reported that a large party entering the district from the south over the snowy divide, finding it impossible to descend the icy mountain slope with pack animals in the ordinary way, lashed the horses' legs to their bodies and started them, packs and all, in bowlder style, down the rugged slope, in which fashion, it is said, they reached the foot of the mountain with only a few fatal accidents.

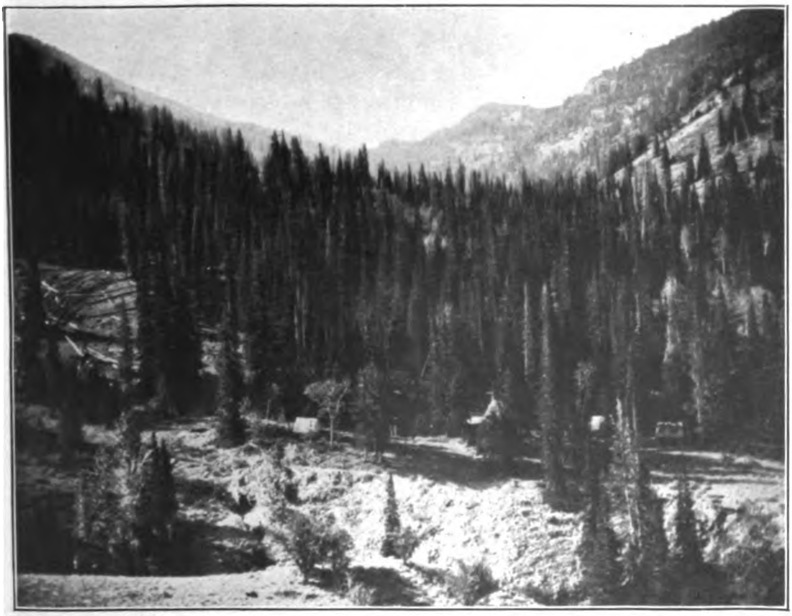
The camp was soon provided with numerous rudimentary hotels, restaurants, and the ordinary commercial and professional enterprises of a mining camp in its early development. A judge and deputy sheriff for the new town were sent in from Elko, the county seat, and until August the Jarbidge mail, sometimes amounting to several pack-horse loads a trip, was sent in gratis by the enterprise of the Elko Commercial Club. The population consisted, on the whole, of intelligent and enterprising Americans, and no disorder of any kind is reported.

A town site was soon laid out, and United States location mineral monument No. 230 was established on the ridge just above the town, between the river and Bear Creek. Town-lot rights or leases were obtained by permit from the forest officer for $10 each, and by March 15 were sold for $10 to $800 each, the price depending on the location. By that date the camp included more than 1,500 people and 300 tents.



A. JARBIDGE, JARBIDGE RIVER VALLEY, AND MOUNTAINS IN OLD RHYOLITE.

Looking S. 10° W.



B. SOUTH BRANCH VALLEY AT HEAD OF JARBIDGE RIVER.

Great Basin divide in background, Ozark lode and Foster camp on East Branch in foreground.
View looking south from Ozark claim, at elevation of 7,700 feet.

It was soon learned that the reports of the Bourne property were grossly exaggerated, and accordingly, in May, a great exodus took place, the emigrants criticizing the country as they went out. Later, however, when the snow had melted away, many "ledges" were found, and a score or more new discoveries were made. Almost weekly up to the present time the discoveries have continued, and the developments are daily proving more promising and substantial.

With the opening of spring and the extension of the road from the Wilkins ranch, passengers and freight were delivered in the camp, and this, by materially reducing the price of merchandise and supplies, further facilitated prospecting. During the summer the trip from Twin Falls to Jarbidge is made by stage in two days and by automobile in a day, the automobile being helped up steep slopes by horses in the last 6 miles of the trip.

Early in the year several mining companies were organized and began operations. The Bourne group was financed, some machinery was brought in by sled, and with improved conditions of travel other companies sent in representatives to visit the camp. The claim holders, however, having in general exaggerated ideas of the value of their ground, held out for high prices and demanded large cash payments, causing hesitancy on the part of capitalists who would bond and develop the properties on a large scale.

Late in the summer of 1910 there were about 300 men in the district, of whom 180 voted at the November election. Although the town was quiet, considerable work was going on in the hills. Mine operators and capitalists investigated the resources of the district, and a company from Denver was examining the character of the ores with a view of installing a customs mill.

Produce and fresh meat were supplied by the neighboring ranches and fruits from the orchards on lower Bruneau and Snake rivers.

In May, 1910, the Jarbidge post office was installed, and a postmaster was appointed, and in October an official mail service (three mails a week) was started from Three Creek, Idaho, 25 miles distant, where connection is made with the mail stage from Buhl. There is also a semiweekly stage service to Rogerson to meet incoming trains on Mondays and Fridays.

Freight rates on ore and merchandise to and from the railroad are said to be $50 a ton, or 2½ cents a pound, in either direction, making the cost of transporting lumber $1 per thousand feet, and other things proportional.

Thus far connection with the district from the south has been made by trail only. Recently, however, the county and the business men of Deeth and Elko have started a good wagon road to connect Jarbidge with the Deeth road at Charleston, 16 miles distant. This road will give the district a direct route to the Southern Pacific Railroad and the Western Pacific Railway at Deeth (see fig. 1), bringing it into commercial relations with Deeth and Elko and giving the camp much lower freight and supply rates.

On the Idaho side, mainly through the business enterprise of the people of Twin Falls, the road to that town is being shortened and materially improved. This road will ascend the Jarbidge River canyon and flats and thus avoid the heavy Rimrock and Jack Hole grades.

The Thousand Springs Power Co., owning a water power just north of Snake River, 25 miles west of Twin Falls, is said to be considering the power needs of the camp with a view of supplying the mines with electric power at the prospective rate of $10 a horsepower a month, with a reduction to $8.25 a month when 2,000 horsepower shall be in use.

There is also assurance of early telephone connections over the line now extending from Elko and Deeth to Gold Creek, 18 miles to the southwest, and also with Hollister or Rogerson on the north.

The Buster mine has a three-stamp mill on the way. A large gang of men are at work on the Pavlak property, where a large mill, planned for both custom and private work, is being installed. According to latest accounts, eight or ten different companies are shipping ore or sacking ore of shipping grade.

For lack of title to the lots on which they desire to build, most of the inhabitants of the district are still living uncomfortably in tents, even in stormy wintry weather. They have petitioned the Government to eliminate from the national forest the most important mineral-bearing portion of the district, included in a north-south rectangular area of about 20 square miles. This area contains little or no timber, and its release would undoubtedly result in great benefit to the mining industry of the district.

Early in 1911 the camp had a population of about 1,200. The generally open character of the winter permitted practically all properties to be reached without difficulty, and work was carried on by a large number of companies, but owing to lack of funds the force was small.

At the mouth of Pine Creek, 3 miles above Jarbidge, a roadhouse and small settlement known as the Hub have been established by the progressive operators of the south end of the district to facilitate delivery of supplies to their camps. The wagon road has been extended for 2 miles above this point and includes the first bridge across the river, a substantial structure.

A plan to consolidate several of the best properties on the ridge south of Bonanza Gulch, including the Bluster, Rock Creek, Success, Sunflower, and others, and work them on a large scale through a main crosscut tunnel, for which the ground is admirably situated, is under consideration by C. J. Nelson and others with the view of enlisting Salt Lake City or Denver capital.

The district as a whole, with only meager development, is more than fulfilling the promise of its surface showings.

PHYSICAL FEATURES.

GREAT BASIN PROVINCE.

The mountain region of Jarbidge lies between two great physiographic provinces—the Great Basin on the south and the Snake River valley or Shoshone Basin on the north. The chief features of the Great Basin, comprising nearly all of Nevada and portions of Utah, Oregon, California, and Arizona,[1] consist of parallel minor ranges of mountains, trending generally in a north-northeasterly direction and separated by detritus-filled valleys.[2]

According to G. K. Gilbert, I. C. Russell, G. D. Louderback, and others, the ranges seem to owe their prominence mostly to faulting of late date, while J. E. Spurr holds that they were probably formed mainly by erosion of the separating valleys. Most of the older rocks in the ranges are folded Paleozoic and Mesozoic sediments cut by many intrusive bodies of porphyry and flooded by lavas. In northeastern Nevada the parallel ranges largely give way to irregular groups that, increasing in altitude from the foothills on the south, merge into the Jarbidge Mountains, which here form the rim of the Great Basin on the north. This portion of the basin is drained mainly by the headwaters of Marys River, which flows into the Humboldt, on the south, at Deeth.

SNAKE RIVER VALLEY PROVINCE.

Toward the north the Jarbidge Mountains slope down to the Snake River valley or Shoshone Basin,[3] which, according to Russell, consists of a vast, nearly level dissected area surrounded by deeply sculptured mountains and extends in a curved course, concave to the north, entirely across the southern portion of Idaho, with a length of about 350 miles and a width in general of 50 to 60 miles.

The master stream is Snake River, which flows in a westerly course longitudinally through the plain, here and there in box canyons, and which, at the west end of the basin, at Huntington, Oreg., enters a deep canyon.

The plain ranges in elevation from about 3,000 feet above sea level on the west to about 6,000 feet on the east. It is mainly of constructional origin and is underlain by Tertiary and Quaternary basaltic lava flows and lake beds.[1] Certain of the lavas were poured out while the lacustrine sediments were being deposited and were interbedded with them. Some of the more recent lavas, according to Russell,[2] are probably not more than 100 years old.

---

[1] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890, Pl. II (opp. p. 6).

[2] The great number and distribution of the ranges in the central part of the basin is comprehensively shown in Bull. U. S. Geol. Survey No. 208, 1903, Pl. I.

[3] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: Bull. U. S. Geol. Survey No. 199, 1902.

A good section of the lavas is exposed in the right or north wall of the canyon just below the celebrated Shoshone Falls. The section beginning with "McKinley Rock," the flow on which the McKinley flagstaff stands, is as follows, in descending order:

Section in Snake River canyon below Shoshone Falls.

	Feet.
Black Snake River basalt, comprising many flows and exhibiting columnar structure more or less throughout	300
Unconformity.	
Reddish and yellowish volcanic breccia	100
Unconformity.	
Massive light-gray to buff rhyolite	300+

The rhyolite, according to S. F. Emmons,[3] approaches dacite in chemical composition and resembles certain modifications of the rhyolite of the Yellowstone National Park.

A good lesser section of the lavas is also well exposed on Salmon River, which joins the Snake from the south at Queens Ferry, 8 miles northwest of Buhl. The exposure is at the Salmon River dam and the crossing of the main Twin Falls and Jarbidge road, about 30 miles south of Twin Falls. Here the gorge of this stream, a steep-walled box canyon nearly 300 feet deep,[4] shows 60 feet of younger black basalt resting unconformably upon the older lavas in which the stream is now sinking its bed.

The region here described is drained mainly by the branches of Bruneau River, which from its source south of Charleston, Nev., runs nearly due north to the Nevada-Idaho boundary line and thence continues slightly west of north for about 80 miles to Snake River, which it joins about 50 miles almost due south of Boise. The next main tributary to the Snake on the east is Salmon River, which flows about parallel with the Bruneau and heads near Contact, Nev. At the State boundary line Salmon River is 50 miles east of the main Bruneau. Bruneau River splits into several branches in Idaho. The main stream flows to the west of the Jarbidge district. The East Fork heads in Nevada just south of the State line, south of Three Creek. The West Fork heads at the Nevada line near the east

---

[1] Lindgren, Waldemar, Mining districts of Idaho Basin and Boise Ridge, Idaho: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, Pl. LXXXVII; map shows rhyolite and basalt, early Neocene. Boise folio (No. 45), Geol. Atlas U. S., U. S. Geol. Survey, 1898. The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 65. Silver City folio (No. 104) and Nampa folio (No. 103), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

[2] Russell, I. C., op. cit.

[3] Report Internat. Geol. Cong., 1891, p. 373.

[4] Oral information furnished by Mr. F. C. Horn, chief engineer in charge of the Twin Falls-Salmon River Land & Water Co.'s dam now being built at this place.

line of the Duck Valley Indian Reservation. Jarbidge River lies east of the main Bruneau and joins it 40 miles north-northwest of its source, near Jarbidge, 14 miles south of the State line.

From the convex edge of the plain on the south, at an elevation of about 4,000 feet, between Salmon and Bruneau rivers, the surface rises in a long, gentle piedmont slope to the Jarbidge Mountains, as shown in the left background of Plate IV, the topography being on the whole in marked contrast with the rugged foothill slope of the Jarbidge Mountains on the Great Basin side to the south. In the vicinity of the State line the elevation in general is about 6,000 feet; 6 miles farther south, at the foot of the high divide (see Pl. III, *A*), about 7,000 feet. The highest ridges attain almost 11,000 feet. Near the headwaters and south of Jarbidge camp the forks of Jarbidge River have cut deep trenches into the elevated volcanic plateau, which reaches its highest point south and east of the town.

The high ground extending northeastward from the Jarbidge district and mountains, usually mistaken for the Great Basin divide, is in reality not the divide, but a long spur.

After a drive of 40 miles over the flat Snake River plains the Jarbidge-bound traveler on the Twin Falls route, crossing Salmon River at the dam, soon rounds on his left (southwest) the toe of a low lava-covered ridge. This ridge, with gradual increase in width and height and with gentle northwesterly slope, is on the left of the route throughout the remainder of the journey. It trends in a fairly direct southwesterly course for a distance of about 40 miles, beyond which it merges into the Jarbidge Mountains and the Great Basin divide proper. Back of the ridge from the traveler's route lie the widely branching headwaters of Salmon River, some of which reach well into the Jarbidge Mountains on the southeast.

Being without a name, the ridge may be appropriately referred to as the Elk Mountain ridge, from the so-called Elk Mountain, its most prominent landmark, in which, near the State line, 25 miles east-northeast of Jarbidge, it culminates at about 8,500 feet above the sea. (See Pl. I, p. 10.)

The ridge seems to be mainly monoclinal, with the rocks dipping gently to the northwest, but in places it may be anticlinal or domed, as at Elk Mountain. It is said to show traces of mineralization interruptedly throughout its extent, and its deposits are being prospected at Elk Mountain and other points.

JARBIDGE MOUNTAINS.

Of the mountains bounding the Snake River valley on the south the Jarbidge Mountains are among the most important and lofty. The great watershed extending irregularly through portions of Wyoming, Utah, Idaho, Nevada, and Oregon, and forming the divide between the Great Basin on the south and the Snake River valley or basin of the Columbia on the north, culminates in the Jarbidge Mountains at an elevation of nearly 11,000 feet.

The mountains are situated mainly around the head of the Bruneau River drainage basin. In the vicinity of the State line this basin has a width of about 60 miles, from a point east of Three Creek, Idaho, to Owyhee, Nev., and contains many tributary streams. It is bounded on the east, south, and west, by Salmon, Humboldt, and Owyhee River basins, respectively.

The Jarbidge Mountains are about 12 miles wide and extend in an east-west direction parallel with the axis of the divide, across Jarbidge River, a tributary to the headwaters of Bruneau, and its East Fork,[1] which drain the area in a northerly direction. The main ridges trend in the same direction, at right angles to the axis of the divide, as shown in Plate II (p. 12). This trend is not wholly due to consequent drainage on a sloping surface of lava flow, as would at first appear, but seems in general to harmonize with the trend of the Great Basin topography on the south and may owe its origin to lines of fissuring or faulting in connection with the epoch of igneous flows and uplift.

The lavas were erupted in at least two distinct and extensive epochs, separated by a considerable time interval, during which subaerial erosion scored the surface and developed a drainage system similar to that of to-day.

The lavas of the later period were more fluidal and resistant than those of the first period. For convenience they may be referred to as the younger or " rim-rock " lava. They were freely poured out, completely flooding the entire lower region and burying a large part of the older lavas, in places to depths of nearly 2,000 feet. This second period of eruption left the Jarbidge Mountain region in the form of a huge elongated east-west dome rising perhaps a thousand feet or more above the present highest peaks and having by reason of the fluidity of the later lavas a comparatively smooth surface.

From the summit of this dome the surface declined in long, gentle slopes in all directions—to the flat-lying Snake River plains, about 20 miles distant on the north, and nearly to the base of Elk Mountain, about the same distance on the east.

On this new constructional domal surface, at the close of the second period of volcanism, subaerial erosion resumed its work of destruction and denudation, and the present drainage system, with its main courses approximately parallel to the lines of the intervolcanic epoch, was established. The higher part of the dome, where precipitation and temperature extremes were greatest and where there were lines of weakness due to volcanism and perhaps crater openings of considerable depths, was most deeply dissected.

---

[1] This stream by some is also called the East Fork of Bruneau River, but this name is preoccupied, as shown on the land-office and other maps, by the 50-mile tributary draining the large Three Creek country to the east. To avoid confusion it seems best to refer to the stream under consideration as East Fork of the Jarbidge.

A notable and economically important feature of this process of denudation was the stripping off of the roof or cover of the dome, the great blanket of the second or younger lavas, which are now worn back to the east side of the East Fork valley on the east and beyond the Jack Creek valley on the north. The eroded edges of these lavas, rising nearly 1,000 feet above Jack Hole and Jarbidge River, form a steep inward-facing scarp or rim rock, which rests upon and encircles the slopes of the mountains on the north and rises to the 10,000-foot contour where it crosses the divide on the east. (See Pl. II, p. 12.)

As soon as the young lava covering became worn through at the summit of the dome, erosion was concentrated along the contact of this covering with the underlying softer old lava formation, and it has been a controlling factor in determining the present topographic features of the district.

Simultaneously and almost coextensively with the stripping back of the young lava covering, the main streams—Jarbidge River, East Fork, and Jack Creek—in their process of down-cutting along the contact and subsequently below it, migrated or shifted their channels laterally down the slope of the dome, the Jarbidge to the west, East Fork to the east, and Jack Creek to the north. This migration of the channels has produced precipitous inward-facing cliffs bounding these streams on the outside of the dome—east of East Fork, north of Jack Creek, and west of Jarbidge River—and contrasting strongly with the long and comparatively gentle slopes on the opposite or inner sides, across which the streams have migrated. It has also resulted in the present occupation by East Fork and the Jarbidge of practically the same drainage lines that existed in the inter-volcanic epoch before the rim-rock lavas were poured out.

The denudation and dissection of the old underlying lavas that followed the removal of the young lava covering has resulted in two distinct types of topography. The one type, shown in Plate IV, generally belongs to the old lava area occupying the heart of the district, from a line west of Jarbidge River to a line east of East Fork, and is adolescent. The other type belongs to the young lava, or piedmont portion of the field, and is young. It is shown at the left in Plate IV.

The old-lava area is at once the most striking and important. It contains the dominant features of the district. These consist of the high, rugged north-south ridge between Jarbidge River and East Fork and the deep valleys of these two streams, which cut below the

6,000-foot contour, or about 5,000 feet below the tops of the neighboring mountains.

Of the culminating peaks, which, as shown on Plate II and to the left of the center in Plate IV, are seven in number and about a mile apart, the most northerly and highest is Jarbidge Peak. This and the four succeeding peaks to the south, which are nearly equal to it in height, are conspicuous to the traveler approaching the district from the Idaho side, being visible for 90 or 100 miles on a clear day. They are commonly known as the Five Peaks, also as the Crater Peaks, Jarbidge Peaks, and Jarbidge Mountains. For convenience of reference in this report they will be referred to as the Crater Peaks or Crater Range.

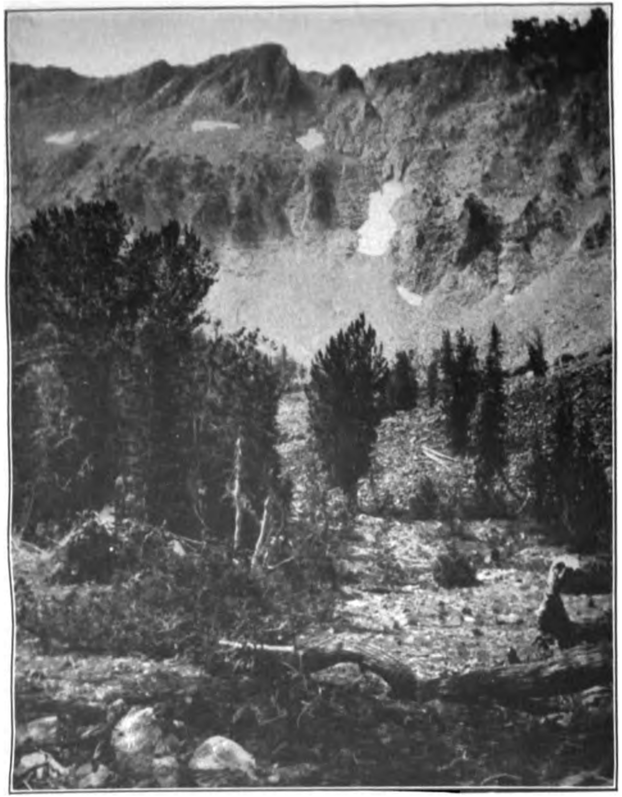
This Crater Range is the most striking feature of the district topographically, geologically, and economically. It exceeds in altitude the Great Basin Divide. It is composed of great masses of volcanic rocks and contains nearly all the mineral deposits of the district.

The topography of the old-lava area is of the type produced mainly by water erosion in an elevated country of horizontally deposited volcanic rocks. It is mainly in the adolescent stage and is characterized by long, high, and in places narrow, though not usually sharp-crested ridges, with smooth or even contours and correspondingly deep, mostly V-shaped valleys and gulches bounded by slopes rising in many places for considerable distances at average angles of nearly 45°. (See Pls. II and IV.) Near the middle of the area, from Jarbidge River to the top of the north end of the Crater Range, the surface rises about 4,300 feet in a horizontal distance of about 1½ miles, or at the rate of nearly 3,000 feet to the mile.

In portions of their courses even the main streams occupy steep-walled box canyons, and in places, as back of the lower part of Jarbidge and west of Bear Creek, the uniformity of the mountain slopes is interrupted by long stretches of vertical cliffs or scarps several hundred to a thousand feet in height, from whose base long trains of talus or rock débris extend down toward the valleys.

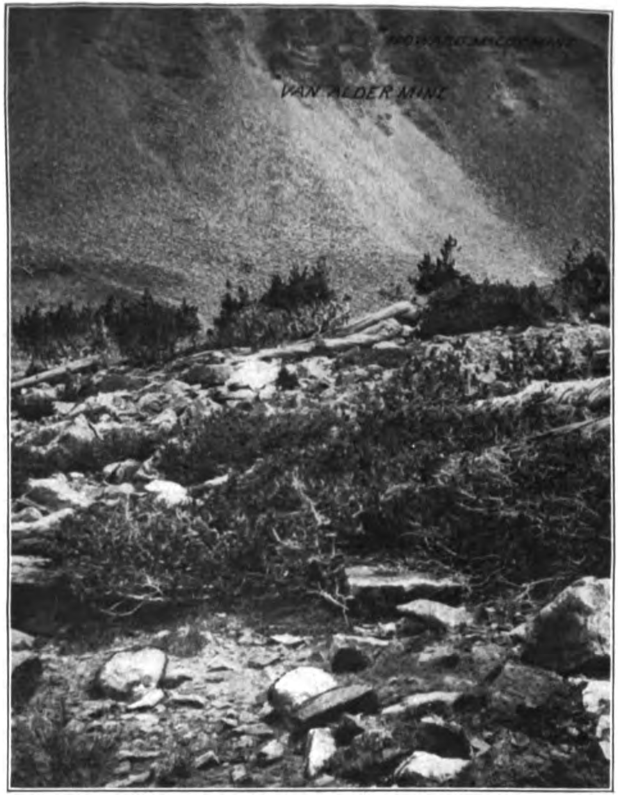
On the east the Crater Range or, more exactly, the saddles of the range, also break off abruptly into steep, high-walled ampitheaters—U-shaped cirques or basins commonly known in this region as "craters"—in which head most of the perennial tributaries of East Fork and Jack Creek.

These basins, which, like the peaks, are situated about a mile apart, and some of which are confined by walls 1,000 or 1,200 feet high on the west (Pl. V, *A*) and separated by long sloping ridges, are known in consecutive numerical order from north to south as First Crater, Second Crater, etc. It is possible, to judge from tuff, breccia, and other volcanic débris observed in the walls, that some



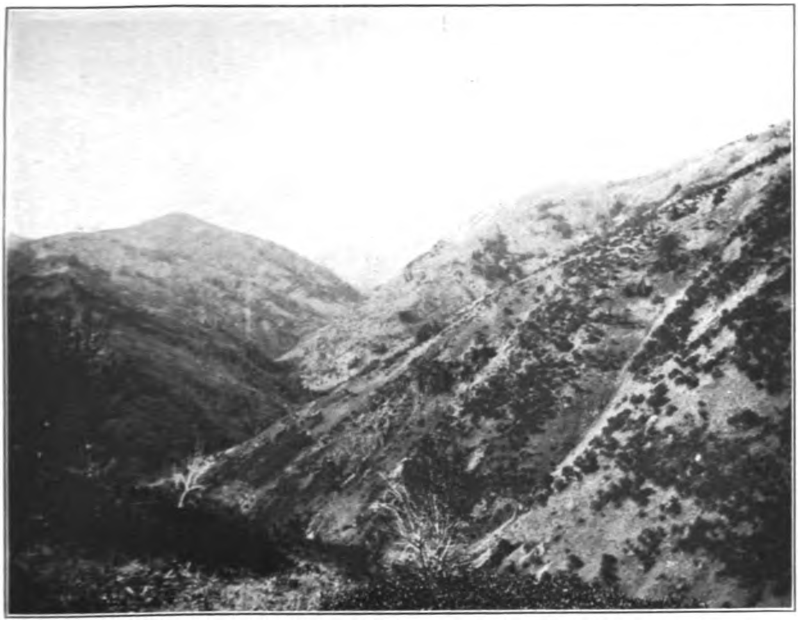
A. PART OF RIM OF FIRST CRATER.

From Little Jack saddle, at elevation of 9,200 feet, looking S. 30° W.



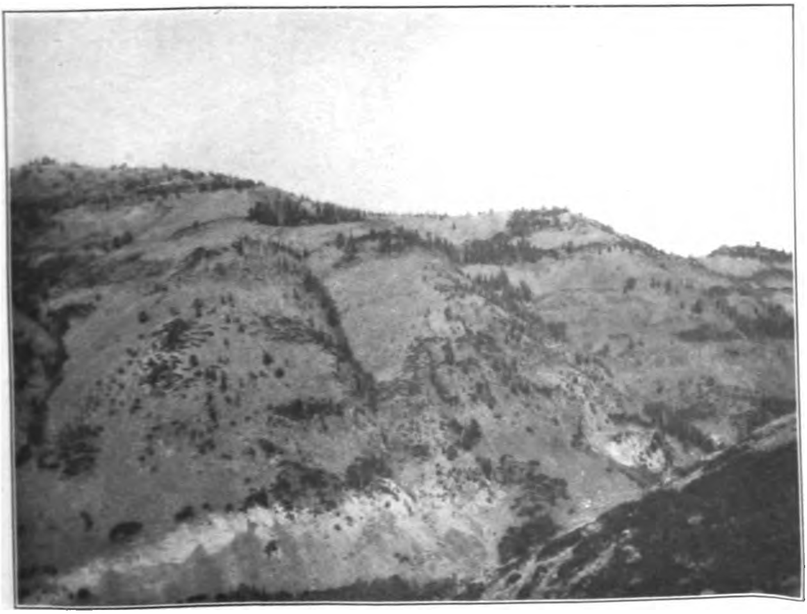
B. VAN ALDER AND HOWARD McCOY MINES, IN SECOND CRATER.

Floor of coarse glacial, snowslide, and avalanche débris in foreground, flanked by belt of steep talus 200 feet high, skirting foot of mural cliff. From floor of "crater," at elevation of 9,500 feet, looking S. 16° E.



A. PINE CREEK VALLEY IN OLD RHYOLITE.

From Pick and Shovel trail, on opposite slope, at elevation of 7,000 feet, looking southeast.



B. OLD RHYOLITES NEAR HEAD OF JARBIDGE RIVER.

Composed of heavy, ill-defined flows or beds dipping gently southwest. From the Ozark mine trail, at elevation of 7,700 feet, looking west across the river.

of the basins may really represent old craters, but time did not permit investigation of this phase of the subject.

The "craters" manifestly owe their origin and general outline to local glaciers that headed in them. They open to the east or northeast, and in this direction their floors slope gently. Since their occupancy by the glaciers their forms have been modified by subaerial erosion, including that of snowslides or avalanches. Snow and ice now remain in some of them throughout the year. They are floored by morainic and other forms of glacial drift and coarse avalanche débris, and the cliffs that confine them on all but the open side are flanked by belts of talus rising with steep slope usually about 200 feet above the floor (Pl. V, *B*). Minor features of snowslide and glacial origin also occur locally along the upper course of the Jarbidge, described later.

The old-lava area on the whole is comparatively free from the impassable precipitous barriers that usually characterize a country of this scale of topography and class of rocks. It is generally accessible to the pedestrian, and with slight detours a horse can be taken into almost any part of it.

The topography of the younger or rim-rock lava area is a young topography and contrasts strongly with that of the old-lava area. It resembles in its main features that of the adjoining Snake River plains. The area consists in general of a gently sloping, rarely benched or scarped mesa or piedmont plain dissected by more or less parallel narrow, steep-walled box or V-shaped canyons, as shown at the left in Plate IV. Its youthful character is due in some measure to the greater resistance of the rocks in which it is carved but mainly to the facts that its relatively dry climate essentially exempts it from the attacks of subaerial erosion and that the streams which rise in the moister mountain regions in crossing it erode only the bottoms of their channels, leaving the sides and upper edges of the valley walls intact.

Jarbidge River, the most important stream, heads in the southern part of the district on the upper north slope of the divide, in the angle formed by the junction of the divide with Crater Range, at an elevation of about 9,000 feet. (See Pls. II and III, *B*.) In the upper part of its course, which trends in a north-northwesterly direction and is of a more or less torrential character in a U-shaped valley, it receives contributions from numerous gulches, the most important of which is Fox Creek, entering from the south, about 3 miles in length. About half a mile below Fox Creek and the ninth standard parallel the river is joined from the southwest by Pine Creek, which is about 5 miles long and approximately equal in volume to the Jarbidge above the confluence. The valley of Pine Creek is sharply cut, with rough topography, as shown in Plate VI, *A*.

Through the remainder of the district the course of the Jarbidge is northerly and its principal tributaries are Bear Creek and Deer Creek on the west and Bonanza Gulch, Bourne Gulch, and Jack Creek on the east.

From Pine Creek nearly to Jack Creek, a distance of about 4 miles, the Jarbidge for the most part flows through a gravel-floored, locally terraced flat about 500 feet in average width (Pl. III, *A*) and has a semigraded course with a fall of about 160 feet to the mile, and is correspondingly swift. In volume of water it is said by W. A. Scott to compare with Clear Creek in Colorado. It is reported to be difficult to ford during spring and early summer. In August, 1910, at Jarbidge it was a fine clear stream about 20 feet wide and 18 inches deep.

After entering the young lava area a short distance above Jack Creek the course of the river is mostly in a box canyon, a feature which has caused the present road to enter Jarbidge over Jack Creek Mountain, the high ridge between Jack Creek and Jarbidge River. The canyon is not deep, however, and as a more or less open though somewhat rugged valley flanks it on the east this part of the course could with moderate cost be made feasible for a highway or even a railroad into Jarbidge.

Jack Creek, which heads in the First Crater and adjoining territory on the southeast, occupies in a sense a piedmont valley bounded by the old lava mountains on the south and the young lavas forming the rim rock on the north. So near do its headwaters lie to a tributary of East Fork that the triangular area to the north between these two streams and the Jarbidge, being almost completely surrounded by water, is commonly known as the island.

Bear Creek and Deer Creek are both fine streams of moderate size and are bordered by timber land in the upper parts of their courses.

East Fork, which drains the eastern part of the district, compares favorably in size with the Jarbidge. The topography of its valley, however, is more rugged, especially on the east. Its course in the young lava area, which it enters in the northern part of the district, is mainly in a narrow box canyon, whose walls have almost a sheer drop in places of nearly 1,000 feet and within the district can be crossed only by making a detour of several miles to the north over a trail by way of Robinson Hole. The Jarbidge wagon road makes a similar detour, and by means of a long "grade" on each side of the canyon crosses at the Wilkins ranch in Idaho, 6 miles below Robinson Hole, about a mile north of the State line. At the north edge of the district at the time of visit, when the water was said to be at its lowest stage, East Fork was a fine, clear stream about 25 feet in width and 9 inches deep. It flows in a semigraded or gently riffled course over a gravel bed, with an estimated velocity of about 4 miles an hour.

It is probable that in both the Jarbidge and East Fork valleys considerable water leaves the district unobserved through the subsurface gravels that constitute the valley floors. Both streams are plentiful in trout. After receiving East Fork a few miles beyond the Idaho line Jarbidge River flows to the Bruneau, about 24 miles north of the State line. From the junction Bruneau River flows a little north of west for about 50 miles across Owyhee County and joins Snake River near the corner of Ada and Elmore counties.

Bruneau River, notwithstanding the fact that in the lower part of its course its waters are largely used for irrigation, is one of the few tributaries whose waters, flowing across the Snake River plains, reach the Snake as perennial surface streams from the south. Among the tributaries of the Bruneau the Jarbidge waters are perhaps the most important.

The extreme southeastern and south-central portions of the district, which are relatively unimportant so far as present mining developments are concerned, drain, respectively, southeastward through Canyon, Cottonwood, and Camp creeks into Salmon River and southward through Marys River into the Humboldt. The extreme southwestern portion of the district drains principally into the main or Charleston fork of the Bruneau.

GEOLOGY.

Like much of the Great Basin on the south and the Snake River or Shoshone Basin on the north, the Jarbidge district lies in an area of folded and tilted, principally Paleozoic sedimentary rocks cut by granular intrusives and flooded by Tertiary lavas, as shown on the geologic map. (See Pl. II.)

The rock groups of the region, beginning with the oldest, are Paleozoic sedimentary rocks, post-Paleozoic intrusive rocks, early Tertiary lavas, late Tertiary lavas, Tertiary sedimentary rocks, and Quaternary deposits. With reference to the mineral deposits the early Tertiary lavas are the most important of these groups. The area of these lavas is approximately outlined on Plates I and II.

SEDIMENTARY ROCKS.

PALEOZOIC SEDIMENTARY ROCKS.

Rocks regarded as Paleozoic occur in the western part of the Jarbidge district and extend southward across the divide into the Great Basin. (See Pls. I and II.) In this vicinity they constitute the north-south range of hills between the Jarbidge drainage basin on the east and that of the main fork of Bruneau River on the west, locally known as the Quartzite Range and also as the Copper Mountain Range, from the prospects of copper that it contains.

These rocks, according to N. W. Sweetser,[1] who assisted the writer and who had previously devoted much time to studying the geology of the district—

> consist, in order of deposition, of quartzite, limestone, and shales. They have been considerably disturbed, faulted, tilted, and folded. They dip steeply to the north at angles of 60° and exhibit a general thickness of several thousand feet. * * * No fossils have as yet been found in them in this part of the field. They rest upon gray, coarsely crystalline hornblende granite, which seems to be intrusive, and they are locally overlain or capped by thin flows of rhyolite. The limestone is cut by dikes of granodiorite of about the same age or slightly younger than the granite.

Near the center of the district are outcrops thought to belong to these old rocks, notably on the west slope of Crater Range. Here, protruding above the surface of the surrounding rhyolite, a quartzite reef, apparently representing an upturned bed or sill, probably in the crest of a buried range, and commonly known as the "quartzite dike," is shown by more or less continuous bold croppings to extend for a distance of about 2 miles in a northeasterly direction diagonally across the mountain side above the Bourne and Buster mines and is recently reported to have been struck in the Pavlak tunnel. It is said to have an average width of about 200 feet and a maximum of about 400 feet. It agrees in trend with the Great Basin ranges on the south and probably represents the crest of one of these old mountains that was long deeply buried by the lavas through which it now protrudes, having been but recently brought to view by erosion and probably faulting. On the northeast, where it crosses Bourne Gulch at an elevation of nearly 7,000 feet, it is about 140 feet wide, dips 80° NW., and shows on the hanging wall some breccia and a little black slate or chloritic and graphitic schist containing needles and lath-shaped areas of sericite and other metamorphic minerals. Where not altered to a relatively massive quartzite by silicification, as it seems to be in most places, it consists of medium-grained whitish or light-gray, very hard quartzite. Except for a few layers of parallel sheeting it is structureless or massive. Persons who have prospected on or along the reef report that no other sedimentary rock is present in association with it.

About half a mile southeast of the quartzite reef above described, to the north of the Bluster and the Pick and Shovel mines, chiefly on the south side of Bonanza Gulch, pale-greenish siliceous shale or sericitic quartzite and conglomerate crop through the rhyolite. These rocks, though regarded as Paleozoic, appear younger than the quartzite reef, with which they are in marked unconformity and which has seemingly supplied much of the material contained in the conglomerate. The outcrops extend interruptedly from the point where the Bluster ledge crosses the gulch, at an elevation of about 7,200 feet, westward down the gulch for about a quarter of a mile, from the It claim on the east across the American Man claim and on to the Arizona Fraction on the west, at an elevation of about 6,800 feet. From Bonanza Gulch the outcrops also rise southward to the top of the ridge, at the north end of the Pick and Shovel claim.

---

[1] Min. and Sci. Press, vol. 101, No. 27, Dec. 31, 1910, p. 871.

The conglomerate, exposing a thickness of about 80 feet, occurs toward the base or lower end of the croppings. It ranges from fine grained and arkosic to coarse and bowldery. It consists mainly of bowlders and pebbles of quartzite, black massive argillaceous rock freely traversed by quartz veinlets, and some old basalt or diabase. It is overlain by impure sandstone or graywacke, which seems to grade upward into the shale. Both the conglomerate and the shale are cut by rhyolite dikes, one of which is about 30 feet wide.

The shale is more or less massive and shows some banding, apparently representing lines of stratification. It resembles some of the shales in the Cœur d'Alene district, Idaho. Though the rocks are somewhat faulted and tilted, they seem in general to dip gently southeastward into the mountain, and their deeply buried strata may be the source of crushed small masses and fragments of shale found in the veins and associated fault gouge higher up in the mountains. Their outcrops on Bonanza Gulch indicate a partial thickness of about 500 feet.

The rocks here described are referred collectively to the Paleozoic on account of their resemblance to Paleozoic rocks observed elsewhere and the well-known wide distribution of such rocks in the surrounding regions.

Some of these rocks, consisting principally of quartzite, limestone, and a considerable amount of shale and slate, are exposed in the Elk Mountains on the Nevada side of the State line, about 10 miles east of the Jarbidge district, and also in the Contact district, on Salmon River, 25 miles east of the southern part of the Jarbidge district, about 15 miles south of the State line. Both of these places were visited by the writer in 1910.

The maps of the Fortieth Parallel Survey show a wide distribution of these Paleozoic sediments on the south. Map IV, which covers an area extending north to parallel 41° 30′, or within 20 miles of the Jarbidge district, shows the Basin ranges and areas of the old eroded rocks in that region to be mostly Carboniferous, surrounded and overlain by Tertiary sediments (Humboldt formation, Pliocene) and, as in the Jarbidge district, flooded by rhyolitic lavas. To judge from reports of prospectors it is also probable that the Pliocene sediments or lake beds extend northward to the southern slope of the Jarbidge Mountains.

The region 25 miles to the west of the Jarbidge district Emmons[1] describes as an area of Paleozoic sediments cut by granodiorite and other intrusive rocks and overlain by Tertiary lake beds and lava flows, and he shows the wide distribution of these old rocks on his map.

In the light of these facts, together with the presence of eroded Paleozoic rocks in and west of the district and in Elk Mountain on the east, there seems to be no doubt that the great pile of lavas composing the Jarbidge Mountains rest upon a surface of eroded Paleozoic rocks that is continuous, beneath the lavas, with that of the Great Basin on the south, Copper Mountain on the west, and Elk Mountain on the east.

The nearest locality at which the detailed section of these Paleozoic rocks has been worked out and their succession is well known is Eureka, Nev. As inquiries concerning these rocks have been made by persons who are investigating the mineral deposits contained in them in the Copper Basin, Cornwell Basin, Gold Basin, Taylor pocket, and other areas adjoining the Jarbidge district on the west, the following Eureka section[1] is inserted as having a more or less direct bearing on these areas.

Emmons reports that in the area covered by his paper—

> none of the sedimentary or igneous rocks have suffered deep-seated dynamic metamorphism such as results in the development of gneissoid or schistose structure and none of them have been deformed in the zone of flow. Around the intrusive granular rocks there is noticeable contact metamorphism, with garnet zones, especially in limestone and in shales.

The present writer finds the same to be true of the Elk Mountain and contact districts to the east, and essentially the same seems to be true of the area bounding the Jarbidge district on the southwest and west.

Geologic section in Eureka region, Nevada.

System.	Formation.	Thickness (feet).	Character.
Carboniferous.	Upper coal measures	500	Light-colored blue and drab limestones.
	Weber conglomerate	2,000	Coarse and fine conglomerates, with angular fragments of chert; layers of reddish-yellow sandstone.
	Lower coal measures	3,800	Heavy-bedded dark-blue and gray limestone, with intercalated bands of chert; argillaceous beds near the base.
	Diamond Peak quartzite	3,000	Massive gray and brown quartzite, with brown and green shales at the summit.
	White Pine shale	2,000	Black argillaceous shales, more or less arenaceous, with intercalations of red and reddish-brown friable sandstone, changing rapidly from one locality to another; plant impressions.

---

[1] Emmons, W. H., A reconnaissance of some mining camps in Elko, Lander, and Eureka counties, Nevada: Bull. U. S. Geol. Survey No. 408, 1910, p. 15, Pl. V.

Geologic section in Eureka region, Nevada—Continued.

System.	Formation.	Thickness (feet).	Character.
Devonian.	Nevada limestone	6,000	Lower strata indistinctly bedded, saccharoidal texture, gray color, passing up into strata distinctly bedded, brown, reddish brown, and gray in color, in places finely striped, producing a variegated appearance; upper rocks massive, well bedded, bluish-black in color; highly fossiliferous.
Ordovician.	Lone Mountain limestone	1,800	Black, gritty beds at the base, passing into a light-gray siliceous rock, with all traces of bedding obliterated; Trenton fossils at the base; Halysites in the upper portion.
	Unconformity.		
	Eureka quartzite	500	Compact vitreous quartzite, white, blue, passing into reddish tints near the base; indistinct bedding.
	Pogonip limestone	2,700	Interstratified limestone, argillites, and arenaceous beds at the base, passing into purer, fine-grained limestone of a bluish-gray color, distinctly bedded; highly fossiliferous.
Cambrian.	Dunderberg shale [a]	350	Yellow argillaceous shale; layers of chert nodules throughout the bed, but more abundant near the top.
	Hamburg limestone	1,200	Dark-gray and granular limestone; surface weathering rough and ragged; only slight traces of bedding.
	Secret Canyon shale	1,600	Yellow and gray argillaceous shales, passing into shaly limestone; near the top interstratified layers of shale and thinly bedded limestones.
	Eldorado limestone [b]	3,050	Gray, compact limestone; lighter in color than the Hamburg limestone, traversed with thin seams of calcite; bedding planes very imperfect.
	Prospect Mountain quartzite.	1,500	Bedded brownish-white quartzites, weathering dark brown; ferruginous near the base; intercalated thin layers of arenaceous shales; beds whiter near the summit.

[a] This name replaces "Hamburg" shale. See Walcott, C. D., Smithsonian Misc. Coll., vol. 53, No. 1812, 1908, p. 184.

[b] This name replaces "Prospect Mountain" limestone. Idem.

TERTIARY SEDIMENTARY ROCKS.

Rocks corresponding to Tertiary sediments are reported by prospectors to occur on the south side of the Jarbidge Mountains, but as that locality was not visited in this work, the following statement taken from Emmons's report[1] is here inserted:

> *Eocene.*—On the northwest slope of the Elko Range, about 3 or 4 miles east of Elko, the Eocene beds are exposed, dipping 35° E. These beds consist of very thin shales, calcareous at some places and silicified at others, and they contain seams of impure coal. They are overlain unconformably by the Humboldt formation (Pliocene), which here consists of a white porous volcanic ash. * * *
>
> *Pliocene.*—In Pliocene time a great lake occupied almost the whole territory between the Wasatch Range on the east and the Sierra Nevada on the west,

---

[1] Emmons, W. H., A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada: Bull. U. S. Geol. Survey No. 408, 1910, pp. 21–23.

extending northward far into Idaho and southward to an unknown distance. This lake Clarence King has named Shoshone Lake, and the beds laid down in it are called the Humboldt formation. These beds are composed mainly of friable gray, white, and drab sandstone and marly limestones, and at many places contain abundant volcanic material, chiefly tuff of a rhyolitic character. Some of the siliceous beds are made up largely of diatomaceous earth. In Bone Valley, just west of the Mallard Hills, which are some 30 miles north of Halleck, Pliocene fossils have been found.

The thickness of the Humboldt formation is at most places unknown, for complete sections are very rare. In the Huntington Valley, according to King, it can not be less than 600 or 800 feet, and occurrences at other places give the impression that the thickness is greater.

The Humboldt formation covers large areas in this part of Nevada. * * * At several places it lies approximately flat and rests unconformably on the upturned edges of the steeply tilted Eocene beds. * * * As a rule, however, the Humboldt formation is not so steeply tilted as earlier formations, and at several places the beds are flat-lying, resting upon the more highly tilted Eocene beds.

QUATERNARY DEPOSITS.

The Quaternary deposits so far as observed are of too small extent to be shown on the scale of the accompanying map and are relatively unimportant. They comprise glacial and snowslide deposits, talus, and alluvium.

Glacial deposits.—As noted on page 25, the series of amphitheaters, or so-called craters, into which Crater Range breaks off abruptly on the east, owe their origin to the action of ice or local glaciers that headed in them. The rock materials (Pl. V, *B*, p. 24) which these and similar neighboring glaciers eroded or transported in their downward course were deposited mainly as sheets of till, bowlder clay, ground moraine, or ridges of terminal moraine in the bottoms or lower side slopes of the upper parts of the valleys. Examples of these deposits occur on the upper course of Jarbidge River, and in the dooryard of Park's place at Jarbidge is a small esker-like gravel ridge, which seems to owe its origin to a subglacial stream. It is quite possible that on certain slopes now covered with slide and talus sheets of ground moraine of considerable local extent, not observed in this work, may occur.

Snowslide deposits.—The snowslide deposits occur mainly as crude fan-shaped accumulations at the mouths of some of the main gulches and craters, of which Snowslide Gulch is a good example. They consist of a heterogeneous mixture of talus or loose, angular rock débris, gulch scour, demolished timber, etc., gathered and mixed by the snowslide or avalanche on its way. They have a maximum extent of about one-fourth of a mile and a thickness of 30 or 40 feet. In places they are cut through to the underlying till by the present streams.

Talus deposits.—Trains or belts of talus or angular rock débris, usually coarse, extend from the foot of the cliffs down toward the valley. Good examples occur about the head of Bonanza and Gorge gulches and at the foot of the cliff in Horseshoe Crater (Pl. V, *B*, p. 24).

Alluvial deposits.—Stream-laid river gravels floor the open portions of the main valleys, especially the Jarbidge Valley, from a point near Pine Creek to the vicinity of Jack Creek, for a distance of about 4 miles, as shown in Plate II (p. 12). They consist mainly of the older lava pebbles and range from fine to coarse, but are mostly above medium size. The deposits have an average width of about 500 feet and a maximum at Jarbidge of about 1,000 feet. At the time of visit they were being exploited at the lower end of the valley, where they show a thickness of more than 14 feet, with bedrock not yet reached.

In the valleys on the south side of the divide, in the direction of Charleston, according to reports of prospectors, occur also accumulations of Quaternary gravels such as floor the valleys between the ranges more or less throughout the Great Basin region.

IGNEOUS ROCKS.

INTRUSIVE GRANITIC ROCKS (CRETACEOUS?).

The oldest igneous rocks are the post-Paleozoic intrusives. They consist of stocks and dikes of granular granitic rocks that intrude the Paleozoic sediments and are considerably older than the Tertiary volcanic rocks next described. The most important of these, according to Sweetser,[1] is a gray, coarsely crystalline hornblende granite that is extensively exposed underlying and intruded into the Paleozoic sedimentary rocks on the southwest and west of the district. This rock seems in general to agree with the prevailing intrusive found by Emmons [2] in the area farther to the west, and, like it, may be found on analysis to stand close to granodiorite.

After the intrusion of the granite both it and the Paleozoic rocks were further intruded and cut by dikes of a similarly granular rock. A small body of this rock outcropping through the sediments and their rhyolite covering occurs on the upper part of Bonanza Gulch north of the Bluster mine. It is a red medium-grained granitoid rock and contains numerous dark or dull-green, roughly equidimensional crystals of hornblende, of which the largest are nearly one-fourth inch in maximum diameter. The microscope shows the rock to be a granodiorite and to be composed essentially of soda-lime and alkali feldspars in about equal amount, hornblende, and quartz. Quantitatively the alkali feldspars are present in the following order: Microcline, microperthite, orthoclase. The microcline is traversed by veinlets of albite and contains inclusions of plagioclase. Optic tests show the plagioclase to be mostly andesine-labradorite. Much of it is considerably kaolinized or altered. In the weathered rock the hornblende is wholly changed by alteration to epidote, which is present in considerable amount, and to chlorite. Accessory minerals present are magnetite in considerable amount, apatite, and zircon.

---

[1] Sweetser, N. W., Geology of the Jarbidge mining district: Min. and Sci. Press, vol. 101, No. 27, Dec. 31, 1910, p. 871.

[2] Emmons, W. H., Bull. U. S. Geol. Survey No. 408, 1910, p. 24.

In describing the occurrence of granodiorites in the area to the west Emmons[1] refers to an analysis as follows:

> An analysis[2] of the rock which constitutes the summit of Shoshone Peak was made by R. W. Woodward. This analysis gives all the iron as ferrous iron, and the norm can not be calculated; but it is sufficient to confirm the classification of the rock as granodiorite. Its composition is very near that of a granodiorite from Pyramid Peak, Eldorado County, Cal., described by Lindgren,[3] and that of other typical granodiorites in California.

Analysis of granodiorite from Shoshone Peak.

[By R. W. Woodward.]

SiO_2	70.17
Al_2O_3	14.53
FeO	4.03
CaO	2.29
MgO	.93
Na_2O	3.25
K_2O	3.35
H_2O	1.53
	100.08

The intrusive granitic rocks, on the whole, are younger than the Paleozoic rocks, which they intrude, and older than the Tertiary lavas, which they do not intrude. From a similar study of their relations to rocks of known age in various parts of the West described by Lindgren, Ransome, and others, Emmons[4] concludes that the rocks are essentially of Cretaceous age. They are very likely of the same general period of intrusion as the batholiths of California and western Nevada. They are of economic importance, for the ore deposits found in association with them in the Paleozoic sediments that are widely distributed in northern Nevada and at Cornwall and Copper basins, and elsewhere on the west and southwest of the Jarbidge district, seem to be genetically connected with their intrusion.

---

[1] Emmons, W. H., op. cit., p. 25.

[2] U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 621.

[3] Lindgren, Waldemar, Am. Jour. Sci., 4th ser., vol. 3, 1897, p. 306.

[4] Emmons, W. H., op. cit., pp. 28-29.

TERTIARY VOLCANIC ROCKS.

GENERAL FEATURES.

The intrusion, deformation, and erosion of the Paleozoic sediments was followed by the eruption of Tertiary volcanic lavas that more or less completely flooded the region. It was early recognized by the Fortieth Parallel and other surveys that the Great Basin shows a variety of Tertiary lavas which are identical over wide areas and were erupted in somewhat the same succession. This succession in general, according to Spurr,[1] whose studies of the lavas in a large part of the Great Basin are among the most recent, is rhyolite, andesite, and basalt.

Among these rocks the most abundant and widely distributed are the rhyolites.[2] The volcanic rocks in the Jarbidge district, as shown by a comparative study with those of the Fortieth Parallel and other surveys, plainly belong to this family. It is quite possible, however, that the rocks of the Jarbidge district may contain also other lavas than rhyolites, but they were not observed in this reconnaissance and, if present, must be in small amount.

The description of Emmons,[3] which gives the chief characteristics of the rocks of the Jarbidge district, is as follows:

> Rhyolites are glassy igneous rocks which have about the same chemical composition as granites. In color they are white, pink, purple, or dark brown. The dense, pasty groundmass may contain phenocrysts of quartz and orthoclase, with small amounts of biotite, augite, and hornblende. A little soda-rich plagioclase may also be present among the phenocrysts. They form surface flows and many of them show streaking due to flowage. Some of them are flow breccias formed of angular fragments of rhyolite in a matrix of the same. Such rocks result when a crust forms over the flow and is broken up by the movement of the still liquid portion, which, solidifying, forms the matrix for the fragments. Some rhyolites are thin, fissile bands which resemble shales. The shaly appearance is probably due to banding that developed as the rhyolite flowed and was emphasized by subsequent weathering along the parting planes. Some are vesicular. The small blebby holes in these rocks represent the places where imprisoned gases expanded when the pressure was removed from the magma at the time of eruption. In some the vesicles are filled with amygdules of amethystine quartz, deposited by water after the rock had solidified.

The rhyolites of the Jarbidge region were erupted in at least two distinct periods, separated by a considerable interval of erosion, and they will accordingly be described as the earlier or old rhyolites and the later rim-rock or young rhyolites.

---

[1] Spurr, J. E., Prof. Paper U. S. Geol. Survey No. 42, 1905, p. 274; Jour. Geology, vol. 8, 1900, p. 642.

[2] U. S. Geol. Expl. 40th Par., vol. 1, 1878, p. 606.

[3] Emmons, W. H., Bull. U. S. Geol. Survey No. 408, 1910, pp. 30–31.

OLD RHYOLITES (MIOCENE?).

OCCURRENCE AND DISTRIBUTION.

The economically most important and interesting of the volcanic rocks are the old rhyolites. On the eroded surface of the Paleozoic sediments the lavas were poured out, mainly in successive broad flows, until they aggregated nearly 6,000 feet in maximum thickness, measured from the bottoms of the old valleys to the top of the neighboring mountains. They seem to have been erupted mainly along a fissure or series of inconspicuous craters or vents coinciding with the axis of Crater Range, whence they spread widely in all directions.

At or soon after the close of eruption the rocks were fissured, in part, perhaps, by contraction due to the cooling of the heated mass, but mainly by crustal movement attended by normal faulting. The fissures thus produced are now occupied by the gold-bearing quartz veins of the district and a few of them by rhyolite dikes.

The erosive processes that followed eruption and gave the region its present surface relief are described on pages 22–23.

The present exposures of these rocks in the district, as shown on Plate II (p. 12), extend from the region beyond the Great Basin divide on the south to Jack Creek, Rimrock, and Robinson Hole on the north, a distance of 12 miles or more, and from the region west of the Jarbidge to and beyond East Fork on the east, a distance of about 9 miles, thus occupying an area of about 100 square miles. Beneath the young lava covering they seem also to have a considerable extent to the southeast, where they are exposed mainly in the deeply cut valleys on the headwaters of Salmon and Marys rivers.

Measured from the summit of Crater Range to Jarbidge River, which is still sinking its bed into these lavas and so far as known has nowhere cut through them to the underlying Paleozoic rocks, the lavas, after having suffered two periods of vigorous erosion, the intervolcanic and the postvolcanic, the latter of which is yet going on, still show a thickness of nearly 5,000 feet. On the west they have been largely removed by erosion, being represented only by thin detached sheets capping the Paleozoic rocks on the summits of the Copper Mountain Range. On the east and north they pass unconformably beneath and are buried by the younger lavas described on pages 42–46.

As seen in their present weathered state in the field, the rocks exhibit a great variety of colors, of which the prevailing is pinkish or reddish ash-gray. Greenish, reddish, and purple tints are also characteristic, and practically the whole northeastern part of the Crater Range is stained a bright brick-red by iron oxide.

The rocks occur in a score or more of flows, resting unconformably one upon another and ranging from 30 or 40 to several hundred feet in thickness. Along Jarbidge River they are not well defined. (See Pl. VI, *B*, p. 24.) On East Fork, according to Sweetser,[1] 12 successive flows cut through by the stream can be counted.

In some localities, as shown in the cliffs back of Jarbidge and along Bear Creek, the flows exhibit a crude columnar structure, a feature found by the Fortieth Parallel Survey developed to a high degree of perfection at Karnak, in the Montezuma Range, Nevada.[2] Some of the flows are also more or less cavernous, examples of which are conspicuous in the high cliffs of the Bear Creek drainage basin, west of Jarbidge. Some of the openings look large enough to admit a man on horseback. At the south edge of the Jarbidge River flats, about three-fourths of a mile above the town, opposite the Buster mines and apparently on the Buster main fissure, occurs one of these features, locally called the Jarbidge Cave. It extends some 60 feet under the mountain, having a width at the floor of about 20 feet and a height of about 16 feet. These caverns were formed mainly by uneven congealment of the lava while yet in motion, and in some of them, as the Jarbidge Cave, faulting and dissolving out of the rock mass by circulating acidic solutions have been important agencies.

Similar features on a smaller scale may be observed in the hand specimen as druses, usually lined with hyalite or opaline chalcedony, examples of which are plentiful on the ridge west of Bear Creek.

The rocks are in the main nearly horizontal. They include locally intercalated sheets of black and brown obsidian or glass and also, particularly in the upper portions, the usual ejecta and coarser volcanic products, such as ash, tuffs, breccias, agglomerates, bombs, and lapilli, more or less widely distributed. On the head of Jarbidge River, to the southwest and west of the confluence of the south and east branches, the flows, as shown in Plate VI, *B* (p. 24), seem to dip to the southwest.

STRUCTURE.

The rocks show gentle folding and some smaller dislocations, particularly along the vein fissures, especially on Bear Creek. Apart from this no pronounced faulting was observed.

The faults, including the vein fissures, seem to be mostly normal. They occur roughly in two groups—the west group, mainly in the west slope of the Crater Range and along Jarbidge River, and the east or Crater group, mainly in the upper east slope of the Crater Range. Those of the west group, as shown on Plate II (p. 12), strike in the main northwestward and dip steeply to the east, into the range; those of the east group strike more nearly north and south, parallel with the range, and dip steeply to the west, into its axis, against the dip of the west group.

---

[1] Sweetser, N. W., Geology of the Jarbidge mining district: Min. and Sci. Press, Dec. 31, 1910, pp. 871–872.

[2] U. S. Geol. Expl. 40th Par., vol. 1, 1878, p. 644, Pl. XXI.

The faults probably represent in the main prevolcanic faults or deformation lines in the underlying rocks, where they reach far beyond the Jarbidge district, and they were subsequently extended upward through the lavas by widespread postvolcanic disturbances. The prevalence of the normal faulting, however, and the synclinal dips of the two fault groups or systems from opposite sides of the axis of the range indicate that some of the fissures are probably also in part due to subsidence of the axis and adjustment that followed the outpouring of the lavas. It is also probable that in places fissuring may have been aided by contraction of the heated lava mass in cooling.

The rocks are cut by rhyolite dikes, which are similar in character to the intruded rock and were probably derived from the same magma. Examples may be seen in Bonanza Gulch below the Pick and Shovel property.

MACROSCOPIC CHARACTER.

The rocks normally consist essentially of a fine-grained dense or aphanitic groundmass with equidimensional phenocrysts of quartz and feldspar ranging from very fine up to 0.2 inch in diameter and giving to the rock a porphyritic aspect. The quartz is by far the more abundant. In places the phenocrysts are so plentiful as to give to the rock the appearance of a medium-grained granite, but in general the groundmass much exceeds the phenocrysts in volume. Banding or flow structure is locally present but not usually pronounced. The rocks in general are considerably altered. In some areas, particularly in the vicinity of vein fissures, they are highly altered by metasomatic replacement, the chief changes being devitrification and silicification of the rock almost as a whole, attended with the development of certain new or secondary minerals described later.

The feldspars, which are mostly orthoclase, are usually much weathered or kaolinized and where corroded out at the surface give to the pebbles in the river gravels and to some long-exposed talus a pitted or pock-marked appearance. The quartz occurs mostly in rounded or globular grains, and though of a vitreous or glassy luster it is rarely clear or white, but ranges from pale reddish or purplish through deep wine color to dark reddish brown. Locally it is known, particularly where strongly colored, as "fish-eye" quartz.

On being mechanically isolated from the parent rock the quartz loses much of its intensity of color and the loss is still further increased by crushing or pulverizing. The finer the division the greater proportionally is the loss, and the microscope shows that the coloring is not uniform in all parts of a given piece of the crushed material. The color is strongest in areas of metasomatic alteration and here the rock, as on the Pavlak property, is also more or less impregnated with secondary pyrite and marcasite rather uniformly disseminated in small macroscopic and finer cubes and grains.

MICROSCOPIC CHARACTER.

Under the microscope the groundmass is seen to range from microcrystalline through cryptocrystalline to glassy. Much of it is felsophyric and in some places it is moderately streaked or banded with flow structure. Some unindividualized glassy base is nearly always present, forming by far the greater part of some slides, and much of it is devitrified. The groundmass is usually microlitic or contains small rods of feldspar, quartz, augitic, and other greenish dark bisilicates, presumably biotite and hornblende, with which in some sections it is heavily charged. These minerals usually lie parallel with the flow structure but in some slides are disposed in axiolitic, radial, or spherulitic arrangement, giving to the rock a spherulitic structure. Locally these spherulites constitute the principal part of the groundmass. In some slides portions of the groundmass are micrographophyric and micropegmatitic and portions contain lithophysæ or small vesicles lined with quartz and feldspar.

The phenocrysts are mainly quartz, orthoclase, and plagioclase, with here and there a little biotite, hornblende, and augite. The feldspars usually show crystalline outline; the quartzes are in general rounded or globular and penetrated more or less by sinuous embayments of the groundmass. In some slides, however, both the feldspar and the quartz occur also in angular fragments that have seemingly resulted from flow breccia and give the slide a clastic or brecciated appearance. The feldspar and quartz, like the other phenocrysts, are irregularly distributed throughout the slide, singly and also in groups of roughly circular or triangular outline in which the crystals and fragments aggregate 30 or 40 in number.

Both the feldspar and the quartz contain glassy inclusions which in places are so plentiful as to form netlike intergrowths with the host mineral. They also contain as small inclusions earlier feldspars, bisilicates, and the accessory minerals including magnetite. Some quartzes and feldspars exhibit frayed or corroded borders. The feldspar as a rule is mostly kaolinized or altered to a kaolinic substance and to muscovite or sericite, and some is altered beyond identification.

The feldspar is principally orthoclase, but microperthite and albite are present in some slides. The orthoclase occurs mainly in tabular and rectangular crystals and some in Carlsbad twins. Plagioclase on the whole is only sparingly present. It occurs mainly in rectangular crystals and is mostly oligoclase. Some of it, however, gives optical tests corresponding to andesine-labradorite.

The deeply colored quartz grains constituting the "fish-eye" quartz under the microscope show clear, with the coloring matter restricted to the fractures and periphery of the phenocrysts. The coloring is therefore not indigenous, nor was it incorporated in the quartz at the time of crystallization, as in smoky quartz, but is due to secondary foreign ferric oxide.

In the portions of the district containing the more highly altered rocks, where devitrification and silicification have been extensive, some feldspars and quartzes are more or less surrounded by a fringe or aureole of secondary silica and adularia, which locally as replacing minerals deeply penetrate the feldspar, particularly the plagioclase. In these rocks there is more or less pyrite and marcasite ranging from microscopic crystals down to small grains and fine dust.

The biotite occurs sparingly in small plates and foils and is mostly altered to chlorite. In a few slides biotite, magnetite, and hornblende seem to have resulted by alteration of augite. The augite, which is of rare occurrence, forms small yellowish-brown crystals. Magnetite, apatite, and zircon occur as accessory minerals.

Secondary minerals, besides the pyrite and marcasite, are sericite, chlorite, hematite, limonite, epidote, kaolinite, hyalite, opaline chalcedony, quartz, adularia, and a little calcite.

Many of the altered rocks are traversed by small macroscopic and miscrscopic veinlets of adularia, quarts, and yellowish chalcedonic or opaline silica, ranging down to less than one-eighth of an inch in width. In some veinlets the filling seems to be exclusively adularia. The veinlets are usually closed, but some are bipartite and are composed of two sets or sheets of adularia crystals, one set frozen end on to either wall, with the opposite ends abutting and interlocking with those of the other set. More generally, however, the veinlet is composed of a single set of crystals, each of which extends, usually obliquely, from wall to wall.

CHEMICAL COMPOSITION.

The determination by the microscope of these rocks as rhyolites is confirmed by the accompanying chemical analysis (A) of a relatively fresh and characteristic specimen of the normal rock obtained in the South Hilltop tunnel 75 feet from the portal. This tunnel is located at the upper end of the town of Jarbidge west of the river.

Analyses of rhyolites.

	A.	B.	C.	D.
SiO_2	76.77	76.80	75.29	71.00
Al_2O_3	12.63	11.64		
Fe_2O_3	1.13	.66		
FeO	.27	.50		
MgO	.07	Tr.		
CaO	.21	.43	.71	
Na_2O	.30	2.53	2.90	
K_2O	6.43	6.69	5.34	
H_2O-	.49			
H_2O+	1.55			
TiO_2	.18			
P_2O_5	.04			
	100.07			

A. Specimen No. 33, old rhyolite, Jarbridge district. George Steiger, analyst.
B. Specimen No. 166, Fortieth Parallel Survey, typical rhyolite, Mopung Hills, Humboldt County, Nev.
C, D. Specimens Nos. 1 and 57, young rhyolite, Jarbidge district. George Steiger, analyst.

The rock of analysis A is the old (ore-bearing) rhyolite. It is a fine-grained, purple-gray, slightly porphyritic rock with a glassy felsitic to microcrystalline spherulitic groundmass and small, irregular phenocrysts of reddish or pale wine-colored glassy quartz and dull, inconspicuous weathered kaolinized and sericitized orthoclase. It is closely banded with fluidal structure and contains sparingly small elongated macroscopic and microscopic druses and parallel veinlets or stringers of apparently secondary quartz, in association with which is developed considerable pyrite. Pyrite in small macroscopic and microscopic cubes and grains is likewise disseminated throughout the groundmass, as is also considerable fine hematite or ferritic material. Magnetite and apatite are present as accessories.

The analysis compares well with those of the typical rhyolites of the Fortieth Parallel Survey. Of the 10 analyses of rhyolites given in the report of that survey, volume 1, opposite page 652, and ranging from 68.84 to 77 per cent in silica, only two exceed this one in amount of silica, and those only by 0.23 and 0.03 per cent.

Comparison with the analyses tabulated by H. S. Washington[1] shows that it is remarkably low in sodium and belongs to an unnamed order of a perpotassic subrang, represented by only one analysis. It is evident, however, that in spite of the fresh appearance there has been much alteration which would have a tendency to increase the percentage of silica and potassium and to reduce that of sodium.

Analysis B is the most siliceous of the analyses of typical rhyolites given in the report of the Fortieth Parallel Survey and is here copied for purposes of comparison. It represents a rock specimen (No. 166) from the Mopung Hills in western Humboldt County, Nev., which, to judge from the description given, is very similar to the Jarbidge rock No. 33 (analysis A). The analyses show a very close agreement between these two rocks in their most abundant constituents, silica, alumina, and potash.

---

[1] Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 125.

Analyses C and D are of the rim rock or young rhyolite. C is a partial analysis of rock specimen No. 1, obtained near the wireless-telegraph station on Telegraph Ridge, 1 mile northwest of Jarbidge. It is a purple or dark reddish-brown aphanitic vesicular lithoidal rock, with small macroscopic drawn vesicles forming part of the general closely banded fluidal structure. Under the microscope it is seen to consist essentially of a brownish to greenish gray, semiopaque felsitic glass, with spherulitic and axiolitic structure, most of which is not resolvable with the lightest-power objective. This groundmass, however, is very uniformly interrupted, to the amount of about one-third the area of the slide, by crudely circular areas of tridymite in its characteristic forms, which seems to be also plentifully present throughout the groundmass. The rock contains as small crystals, or rather fragments of crystals, a little orthoclase, a very little plagioclase which gives tests corresponding to oligoclase, a little biotite, altered hornblende seemingly derived from augite, a very little quartz, and considerable hematite, which is especially prominent about the peripheries of the tridymite areas.

Analysis D represents rock specimen No. 57, from the northeastern part of the district, about a mile southeast of Robinson Hole, where the trail in leading up out of the Robinson Creek canyon reaches the top of the rim rock and the edge of the plain on the east. This is a medium-grained black rock of vitreous luster resembling pitchstone. It consists essentially of dark-gray microlitic glass, charged with feldspathic and augitic (?) microlites, the whole showing very perfect fluidal banding, with subordinate areas of spherulitic structures. Resting in the glassy groundmass are a few small crystals or fragments of crystals of orthoclase, sanidine, a little biotite and augite, the latter mostly altered to hornblende, and a little plagioclase (oligoclase-andesine). Magnetite, hematite, and limonite are also present.

YOUNG RHYOLITES (PLIOCENE?).

OCCURRENCE AND DISTRIBUTION.

After a considerable time interval of volcanic quiescence and vigorous subaerial erosion, the young rhyolitic lavas were poured out from essentially the same vents as the old lavas. They covered the deeply eroded surface of the old rhyolites, and the marked unconformity between the two formations is plainly seen in the northern and western parts of the district. (See Pl. II.) Here they form a gently outward-sloping piedmont plain which, extending beyond the district, merges into the flat-lying Snake River plain on the north and reaches the foot of Elk Mountain, 10 miles distant, on the east.

Other vents were probably situated in this latter direction. The rhyolitic lavas seem also to have a wide extent to the southeast and south, on the headwaters of Salmon and Marys rivers, respectively.

These lavas were poured out at greater elevations than the old lavas; they were also more liquid and, being erupted in successive homogeneous flows that lay conformably one upon another, they spread widely and reflooded the entire district more extensively than the old lavas, though not so deeply, and gave to the Jarbidge Mountains roughly the form of a huge east-west dome. On the outskirts of the district they rest in places upon the old eroded floor of Paleozoic rocks, as in the northwestern part of the district and adjoining territory. Within the district they are best exposed on the north and east, where the eroded edges of their flows that terminate the surrounding plain form the inward-facing scarp or rim rock, bounding Jack Creek valley on the north and East Fork on the east.

In the valleys and low places the lavas attained a considerable thickness, probably almost 2,000 feet, as may be inferred in the vicinity of the junction of Jack Creek with Jarbidge River, where they still show a section of more than a thousand feet. At the summit of the dome and the rim of the crater, however, by reason of their fluidity and the steeper slopes, their thickness probably did not much exceed a few hundred feet.

Owing to the unevenness of the floor on which the lavas rest and to later erosion, their contact with the underlying old lavas is very irregular, as shown on the map (Pl. II, p. 12), in the northern part of the district, particularly from Jack Hole westward. After crossing Jack Mountain near the wagon road, the line descends westward into Jarbidge Valley to a point near the forest station and about 400 feet above the river; this figure approximately expresses the depth to which the river has at this point sunk its channel into the old underlying lavas during the present period of erosion. Here the contact line is sharply deflected to the north and crosses the river at a sharp angle about a mile farther downstream, near the 5,800-foot contour, whence it bends back on the opposite side and crosses Telegraph Ridge 2 miles to the southwest, at an elevation of about 7,500 feet, between the Elko wagon-road pass and the wireless-telegraph station, which stands upon this rock north of the contact.

The young rhyolites occur mainly in homogeneous fine-grained flows conformably superimposed one upon another and dipping gently away from the mountains in quaquaversal manner. They are as a rule closely though in places dimly banded by fluxion structure parallel with the flows and are practically free from volcanic ejecta. In color they are prevailingly dull reddish purple and reddish brown, but they contain also locally intercalated sheets of finely tuffaceous and vesicular phase which are drab, dull greenish, and glassy black.

In places they are very gently folded and slightly faulted, but compared with the old underlying lavas they have been on the whole not much disturbed or deformed. So far as observed none of the dikes, veins, or fissures so freely traversing the old lavas occur in these rocks.

MACROSCOPIC CHARACTER.

These rocks are lithoidal. They contrast strongly with the old rhyolites above described, having a much more basic appearance. To the local prospectors and mining engineers they are known as basalt. In a few places they are medium grained or moderately porphyritic. They consist almost wholly of a dark-reddish or brownish-purple aphanitic groundmass, which usually is more or less closely banded by flow structure and grained and streaked by drawn vesicles, some of them minute. Macroscopic minerals are usually absent and if present are so few and small as to form a negligible percentage of the rock. They occur as mostly glassy laths or needles and short prisms of plagioclase and a little orthoclase, ranging from mere specks to scarcely 0.1 inch in maximum diameter. Visible quartz is usually lacking. In the glassy pitchstone tuffaceous phase, however, which seems to occur mainly in the upper part of the section, the rock has a medium-grained appearance and may contain feldspar phenocrysts 0.2 inch in maximum diameter. The rock has a more or less conchoidal fracture and weathers to a purplish or dark reddish-brown color due mainly to oxidation of its iron content.

MICROSCOPIC CHARACTER.

Under the microscope the rock is seen to consist mainly of a pale greenish-gray to brownish semiopaque groundmass ranging from vitreous to felsitic or, in exceptional cases, microcrystalline. The groundmass contains, besides microlites of feldspar, quartz, and augite, dark and more or less opaque cuneiform and variously shaped grains and dust of ferritic minerals. It is generally characterized by closely banded and woody-grained flow structure, in places developed to a high degree of perfection, the flow lines curving beautifully around phenocrysts that dam their courses.

The continuity of the groundmass is interrupted by more or less equally spaced small, crudely circular or elongated, axiolitic, nearly transparent areas occupied by tridymite. In some slides these areas are perfect spherulites; here and there the macroscopic structure becomes spherulitic with visible tridymite. The tridymite occurs mainly in crudely fan-shaped crystalline aggregates of tilelike, feebly polarizing forms. Tridymite probably constitutes the greater portion of the rock; this conclusion is confirmed by partial chemical analysis

(C, p. 41) of a characteristic specimen of the rock from Telegraph Ridge 1 mile west of Jarbidge.

According to Rosenbusch[1] tridymite is a common constituent of rhyolite. Zirkel,[2] however, states that in the rhyolites of the Fortieth Parallel Survey tridymite is of rare occurrence, and adds that—

> This may in some way be consequent upon the great quantity of quartz present in most of these varieties; for it has been stated, as a result of observations of European rocks, that an abundant secretion of quartz is unfavorable to the formation of tridymite in the same rock.

With these observations the rhyolites of the Jarbidge district seem to be in full accord, for in the old rhyolites, which, as has been shown, are rich in normal quartz, no tridymite was found, while in the young rhyolites, which contain little or no quartz, tridymite seems to be the chief constituent of the rock.

Associated with the tridymite, usually toward the periphery of each area, is considerable hematite, which seems to be primary. It occurs in deep-red plates and in the groundmass in irregular smaller forms, grains, and dust, and seems to be the ingredient which imparts to the rocks their reddish or purplish color. Associated with the hematite as an alteration product and clouding the groundmass in places is also much brownish limonite.

Resting in the groundmass, from 6 to 12 millimeters apart, occur a few small incomplete phenocrysts or more commonly fragments of crystals of feldspar and quartz and rarely biotite, hornblende, or augite. The quartz tends to be rounded in outline; the feldspar, which is mainly plagioclase, with a less amount of orthoclase, is mostly in angular broken fragments.

Small feldspars of an earlier generation and some magnetite occur as inclusions in both the feldspar and the quartz phenocrysts, but the more common inclusions are those of the greenish and brownish glassy groundmass, which also penetrates the phenocrysts as tongues and embayments. A crystal of augite partly inclosed by orthoclase shows the former mineral to have been formed before the latter.

The plagioclase is mostly oligoclase-andesine. Magnetite is present as large and small grains, mostly in association with hornblende and augite. Other accessory minerals observed are apatite and zircon.

Some of these rocks contain a little pyrite, which is probably secondary, but they show practically none of the metasomatic or propylitic alteration occurring in the old rhyolite.

In the table on page 41 the partial chemical analysis (C) of a characteristic specimen of these young rhyolites, collected from Telegraph Ridge, about a mile southwest of Jarbidge, and containing very little quartz, shows a remarkably high percentage of silica for a rock of so basic an appearance—less than 1.5 per cent lower than that in the analysis (A) of the old rhyolite, which is shown to be rich in quartz. Analysis C also shows that the silica must be contained almost entirely in the groundmass, either as tridymite or in some other form. In lime, soda, and potash content it stands close to analyses A and B and shows that in composition the rock on the whole is normal rhyolite.

---

[1] Rosenbusch, H., Microscopical physiography of the rock-making minerals (tr. by J. P. Iddings), 3d ed., p. 177.

[2] Zirkel, F., U. S. Geol. Expl. 40th Par., vol. 6, 1876, p. 202.

The partial analysis (D) of a specimen of the glassy pitchstone black rock from the top of the piedmont rim rock in the northeastern part of the district, which is the most basic rock encountered in the region and which, carrying considerable augite, under the microscope presents the appearance of quartz-bearing andesite, shows this basic phase of the rock to contain 71 per cent of silica, which is more than 2 per cent above the lowest and only a few per cent below the average of the rhyolites of the Fortieth Parallel Survey.

AGE OF THE VOLCANIC ROCKS.

Formations of known age fixing closely the age of the Tertiary rocks above described do not occur in the Jarbidge district. According to King,[1] the rhyolites of the Fortieth Parallel Survey in Nevada are post-Miocene and their earliest eruption is contemporaneous with the first Pliocene beds. King says:

> The extravasation of rhyolites was a feature of the orographical disturbance which followed the dislocation of the Miocene rocks, and the earliest accumulations of Pliocene contain products of the first rhyolitic eruption. In many places, however, notably northeastern Nevada, the outpourings of rhyolite continued well into the Pliocene period, and a vast amount of the Humboldt Pliocene of that region is made of the acidic ejecta of the rhyolitic period laid down in the fresh-water lakes as local tuff beds. * * * Rhyolitic eruptives were characteristic of the opening of the Pliocene and extended over perhaps the first third of the Pliocene epoch.

From similar evidence—rhyolitic ejecta, etc., contained in lake beds—furnished by later and more detailed work in the area to the southwest, Emmons[2] concludes that the rhyolitic eruptions probably began in early Miocene time and continued through the Pliocene. The rhyolites that deeply flooded the Owyhee Mountains in the region about Silver City, Idaho, are referred by Lindgren[3] to the Miocene epoch and regarded as being erupted simultaneously with the great flows of the Columbia River basalt. Their deformational features, faulting, fissures, and ore deposits are similar to those of the older lavas in the Jarbidge district.

---

[1] King, Clarence, U. S. Geol. Expl. 40th Par., vol. 1, 1878, p. 606.

[2] Emmons, W. H., Bull. U. S. Geol. Survey No. 408, 1910, p. 35.

[3] Lindgren, Waldemar, Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 116.

As the Mount Bennett rhyolite of Russell[1] in the region near Mountain Home, Idaho, bears similar relations to the lavas of Snake River to those borne by the rhyolites of the Silver City region, and as it resembles and is correlated by Russell with the rhyolite underlying the Snake River plains, as exposed at Shoshone Falls, which King,[2] under the name of trachyte, refers to the Miocene, it seems probable that the rhyolites of Mount Bennett and Shoshone Falls are of the same age as those of the Silver City region and are probably Miocene. Therefore, to judge from the rhyolites in the surrounding regions, it seems probable that the rhyolites of the Jarbidge district range from Miocene well into the Pliocene. The older rhyolites are regarded as late Miocene and the younger ryholites as near middle Pliocene and possibly later.

It is very likely that field work extended either to the lake beds of the Snake River plains on the north or to the Humboldt formation in the Great Basin on the south will determine definitely the age of these lavas, especially of the younger series.

MINERAL DEPOSITS.

The Jarbidge district shows at least two distinct periods of mineralization. The deposits here described occur in two sharply contrasted groups that differ considerably in age—the early, occurring in or associated with the sedimentary and early granular intrusive rocks, and the late, occurring in the rhyolite. The former are probably Cretaceous and the latter are regarded as post-Miocene.

EARLY DEPOSITS (CRETACEOUS ?).

The older deposits occur in the sedimentary Paleozoic rocks and their associated early granular intrusives, granodiorite, etc., in the western part of the district and the adjoining region. They could not be reached by the writer in this work and are known mainly from oral accounts of mining men and prospectors. They are said to occur chiefly as tabular fissure veins containing gold, silver, copper, and lead in quartz gangue, but they probably include also contact-metamorphic and replacement deposits in the limestone, such as were observed in the Elk Mountain and Contact districts on the east and were also found by Emmons[3] in the area on the west, where they have associated with them a great variety of minerals, which are mostly metamorphic.

The deposits occur mostly near the contact between the Paleozoic sediments, especially quartzite and limestone, and the granular intrusives, and both classes of these rocks are cut by the veins. They seem to have been formed by thermal solutions after the intrusion of the granite and granodiorite, which, as shown under "Geology," are regarded as of Cretaceous age. According to Sweetser[1] the veins are numerous and small. They strike northeast and southwest and have produced some placers.

---

[1] Russell, I. C., Bull. U. S. Geol. Survey No. 199, 1902, p. 42.

[2] King, Clarence, U. S. Geol Expl. 40th Par., vol. 1, pp. 192–193.

[3] Emmons, W. H., Bull. U. S. Geol. Survey No. 408, 1910, pp. 40–41.

These deposits, in part at least, have been known for sometime. They have received attention at the Cornwall, Copper, and Gold basins, mainly on the southwest, and at the Taylor pocket on the northwest, and some of them are said to be promising, but owing to the high cost of transportation and increase in baseness of the ore with depth, extensive developments have not yet been undertaken. At the Cornwall Basin and Taylor pocket they occur chiefly in quartzite and limestone.

LATE DEPOSITS (POST-MIOCENE).

OCCURRENCE AND DISTRIBUTION.

The later and more important deposits, which led to the recent discovery of the Jarbidge district and are now attracting so much attention, occur chiefly as tabular, gold-bearing quartz fissure veins or lodes in the old rhyolite, with which, so far as this district is concerned, they are roughly coextensive. They are in general well defined, being more or less sharply separated from the country rock, and contain angular inclusions of rhyolite, sedimentary rocks, and seams of clay. Many of them have 1 to 8 inches of gouge on either wall. They seem very obviously to belong to the—

> important division of the propylitic veins, which were formed, in most cases, since the Miocene period. Among their characteristics is a peculiar alteration of the adjoining wall rock and a tendency to contain both gold and silver, the value of the latter being usually greater than that of the former. The most prominent representative of this propylitic group is the Comstock lode, which is credited [1878] with a production of $368,000,000.[2]

The veins are about 40 in number. They are associated with the Crater Range or seat of volcanic eruption. They lie mainly between Jarbidge River and East Fork and are mostly comprised in a belt about 4 miles wide extending from Jack Creek on the north to the divide and the head of Jarbidge River, 7 miles distant, on the south. Most of them are on the lower slope and upper east slope of the Crater Range and in general they have a north-northwesterly strike, in places gently curved, and a nearly vertical dip, as shown in figure 2.

---

[1] Sweetser, N. W., Min. and Sci. Press, vol. 101, No. 27, p. 872.
[2] Trans. Am. Inst. Min. Eng., vol. 33, 1902, p. 830.

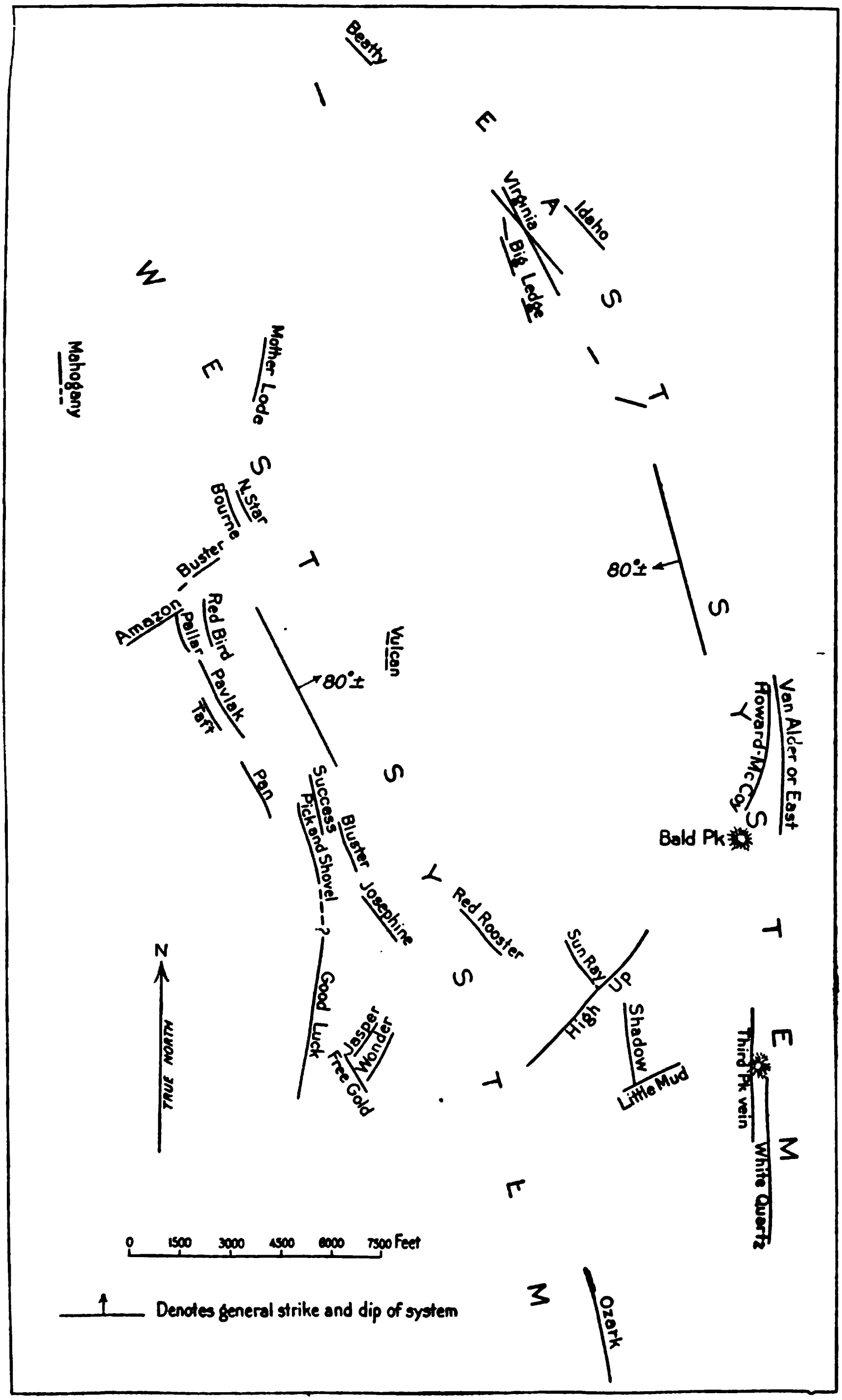


FIGURE 2.—Diagram showing trend and relative position of the principal veins in the Jarbidge district.

They range from 1 to 20 feet or more in width and from less than 1,000 feet to several miles in length. Their outcrops, many of which are bold, prominent reefs, rising in places 60 feet or more above the surface (see Pl. VII), extend interruptedly from 6,000 to 10,800 feet in elevation and show a vertical range in some individual veins of nearly 2,000 feet. Deep shafts have not been sunk on these veins, but it seems very probable that most of them penetrate the underlying sedimentary and granitic rocks, like the veins in the Silver City-De Lamar district, Idaho, to which the Jarbidge district is geologically and mineralogically very similar.[1]

The veins in general consist of two main systems or groups which, starting at the head of Jarbidge River and the junction of the Crater Range with the Great Basin Divide on the south, gradually diverge northward into the western or Jarbidge River group and the eastern or Crater group; these groups, however, are not everywhere sharply differentiated.

The veins of both groups occupy chiefly normal fault fissures, which seem to have been produced mainly by regional disturbances and in part by a sinking or parallel down-faulting of the axial portion of the range that followed the first period of eruption, in consequence of which the fissures on either side dip steeply in opposite directions into the range, the east group to the west and the west group to the east. The two groups converge downward, and it is probable that some of them meet or intersect in the deeply buried axial portion of the range. It seems also probable that in some places fissuring may have been aided by lateral contraction due to cooling of the heated lava mass.

In the fissures produced by extensive regional faulting more or less regularity in strike, dip, and vein content is to be expected, but in those due to local postvolcanic sinking and adjustment of the range there should naturally be more variations, including probably in most cases change in dip at the contact of the lavas with the underlying older rocks.

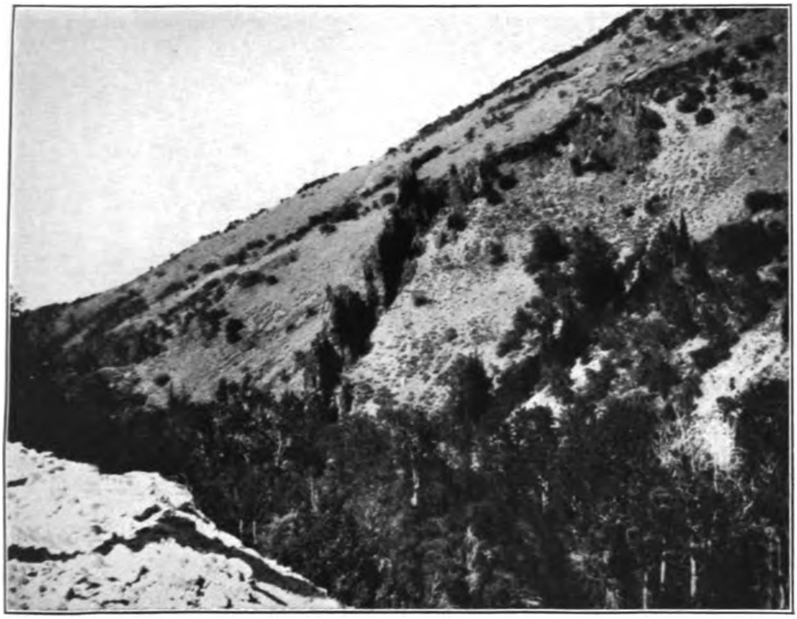
WEST SYSTEM.

The western edge of the mineral belt, comprising the veins of the west system, crosses Jarbidge River obliquely near the mouth of Bonanza Gulch and the Pavlak mine, whence it continues north-northwestward across the lower part of Bear Creek near the elbow nearly to Telegraph Ridge Pass. Half a mile northwest of Jarbidge it includes the Mahogany vein and to the south of this the ridge between the lower part of Bear Creek and the river.

This system of veins comprises the wider and more important deposits, such as the Pavlak, Bourne, Buster, Pick and Shovel, and

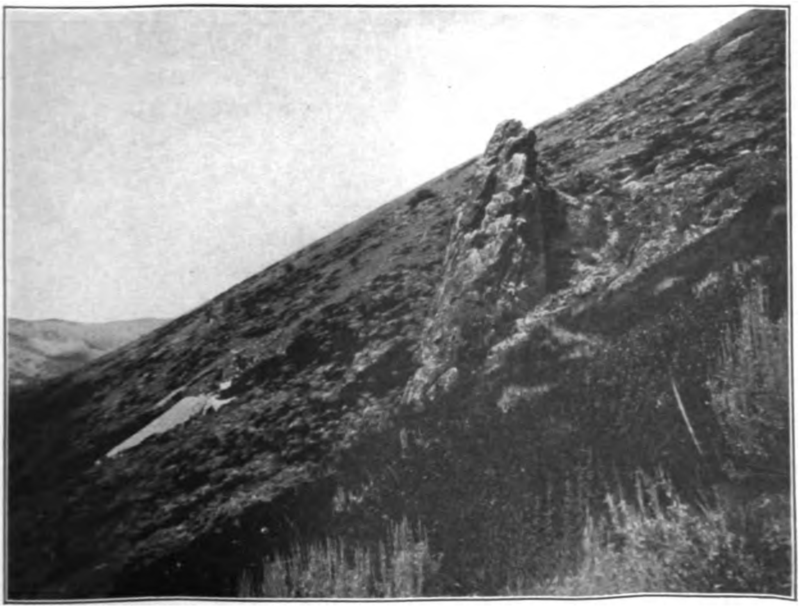
---

[1] Lindgren, Waldemar, The veins of Silver City and De Lamar, Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, 107–189.



A. BUSTER VEIN OUTCROP.

Shown as bold, dark, dikelike wall ascending slope of mineralized belt. From Park lease, at elevation of 6,400 feet, looking N. 30° E. across Jarbidge Valley.



B. PICK AND SHOVEL MINE AND OUTCROP OF PICK AND SHOVEL VEIN.

From the west (normal) slope of the Crater Range, at elevation of 7,400 feet, looking N. 8° W.

Bluster, on which the most extensive development work in the district has been done. These veins lie mostly between elevations of 6,000 and 8,000 feet, at a considerably lower geologic horizon than the veins of the Crater group. They also contain the most prominent croppings in the district. They are nearly all easily reached by wagon road or trail from the Jarbidge River valley. As shown in figure 2, they strike in general north-northwest and dip east into the mountains at angles of about 80°. They contain more brecciated material and their walls are more irregular, less sharply defined, and show more extensive propylitic alteration than the veins of the east system.

The most important of these deposits are concentrated in a belt about a mile wide and 3 miles long, bounded on the west by Jarbidge River and extending from Bourne Gulch on the north to Gorge Gulch on the south.

EAST SYSTEM.

The east or Crater group of veins, represented at the time of visit mainly by the Van Alder and Howard-McCoy veins, occur on the upper east slope of the Crater Range, mostly between elevations of 9,000 and 10,800 feet (the crest of the range). They extend from Jack Creek on the north more or less throughout the series of "craters" or glacial cirques and their intervening ridges, nearly to the Great Basin divide on the south, a distance of about 7 miles. They are best reached by way of the Jack Creek and East Fork valleys or by going across the divide from the head of Jarbidge River.

These veins in most respects contrast strongly with those of the west system. As shown in figure 2, they have a more nearly north-south strike than the western veins, and they dip about 80° W., into the mountain, in opposite direction to the dip of the veins of the west system. Their outcrops, which are usually inconspicuous, show a vertical range of more than 4,000 feet. So far as their present exposures are concerned they mostly occur at geologic horizons nearly 2,000 feet higher than the western veins. They are narrower, being usually from 1 to 4 feet in width, and are more persistent horizontally, some being said to have a length of 3 miles and to extend interruptedly for 6 or 7 miles. They are more sharply defined, with clean-cut walls, and they are closely, definitely, and in places beautifully banded.

These veins occupy mainly normal fissures produced seemingly in part by subsidence or down-faulting of the axial mass of the range, with which they are nearly parallel. The walls are free, and the footwall generally carries from 1 to 8 inches of clayey "talcose" gouge. The bands within many of the veins are separated by thin seams of gouge, which appears to be of shale or slate origin.

CROSS SYSTEM.

Besides the two main systems above described there is also a subordinate system whose veins strike northeasterly, almost at right angles to the two main systems. This third system, which for convenience may be referred to as the Buster or cross system, is represented along Jarbidge River by the Buster and Amazon veins, on the north by the so-called cross veins of Jack Creek, and on the south, toward the head of Jarbidge River, by the Jasper, Wonder, High Up, and Little Mud veins. (See fig. 2.)

STRUCTURE AND COMPOSITION OF THE VEINS.

The minerals of these deposits are adularia, apatite, argentite, calcite, chalcedony, chlorite, epidote (?), fluorite, gold, gold-silver alloy, hematite, hyalite, kaolin, limonite, manganese oxide, marcasite, muscovite, opaline silica, orthoclase, pyrite, quartz, sericite, silver, silver gold alloy, and talc.

The veins are composed mainly of a characteristically laminated pseudomorphic milk-white quartz-adularia gangue, which in the croppings and surface workings is usually stained reddish brown to blackish and yellowish by iron and manganese oxidation products. Some of them, as the Pavlak and the Pick and Shovel, also contain considerable fault breccia or fragments of silicified rhyolite country rock, fragments and seams of the underlying shale, slate, or quartzite, and seams or stringers of talc, from all of which it is inferred that more or less faulting or movement accompanied and followed the fissuring and subsequent veining. Some veins also contain small or minute parallel dikelets that were injected after the veins were formed, as shown in the Van Alder mine of the Crater or east system. These dikelets are probably contemporaneous in age with the dikes of the first period described under "Geology" (p. 33), whose age, however, relatively to the veins, has not yet been determined. In the quartz-adularia gangue quartz is on the whole the dominant mineral, but it is seemingly in all the veins more or less profusely intergrown with adularia, and in some veins the adularia, although not macroscopically prominent, greatly exceeds the quartz and constitutes the bulk of the vein. Specimens examined from the west group of veins show from 10 to 60 per cent of adularia, and from the Crater group as high as 90 per cent.

Adularia is a variety of orthoclase free from sodium, semitranslucent, and with characteristic crystal form. It was first discovered in the western United States by Lindgren in the veins of Silver City and De Lamar, Idaho, in 1897, since when it has been recognized at several other places, notably at Tonopah by J. E. Spurr, in southeastern Nevada at the Gold Springs district, and in adjoining parts of Utah by B. S. Butler, and in the Black Mountains of Mohave County, Ariz., by the present writer. Its abundance in some of the Jarbidge veins is of unusual interest, especially as quartz is looked upon as the ordinary if not universal gangue mineral of auriferous veins. As explained on page 54, the amount of adularia present and the manner of its occurrence are best shown under the microscope.

The following is an analysis of a general sample of the ore from the Bourne mine:

Analysis of ore from Bourne mine.

[George Steiger, analyst.]

SiO_2	72.28
Na_2O	.20
K_2O	11.84

From this analysis and from the composition of adularia as given in Dana's "System of mineralogy" it is calculated that the amount of adularia present in the Bourne ore is 70.65 per cent. The rest of the ore consists of 13.67 per cent of free silica and 15.68 per cent of undetermined constituents, presumably for the most part alumina and other impurities. Except that it shows about twice the amount of potash the analysis is markedly similar to that of the country-rock rhyolite given on page 41 (analysis C).

Comparison of the microscopic sections of this ore with sections from the Crater veins indicates that much of the Crater ore probably contains more than 90 per cent of adularia and about 15 per cent of potash and will compare favorably with the two following analyses of selected specimens of adularia:

Analysis of adularia from the Black Jack mine, Silver City, Idaho.[1]

[W. F. Hillebrand, analyst.]

Silica (SiO_2)	66.28
Alumina (Al_2O_3)	17.93
Potassa (K_2O)	15.12
Soda (Na_2O)	.25
Undetermined	.42
	100.00
Specific gravity	2.54

Determination of alkalies in adularia from the Trade Dollar mine, Silver City, Idaho.[1]

[George Steiger, analyst.]

K_2O	14.95
Na_2O	.20

---

[1] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 167.

A striking feature of the Jarbidge gangue is its characteristically laminated or platy and bladed structure, in which innumerable contiguous or connecting laminæ or plates are variously arranged. This material is aptly termed by the miner "fish-scale quartz," from the adjacent plates partly overlapping one another. (See Plate VIII.)

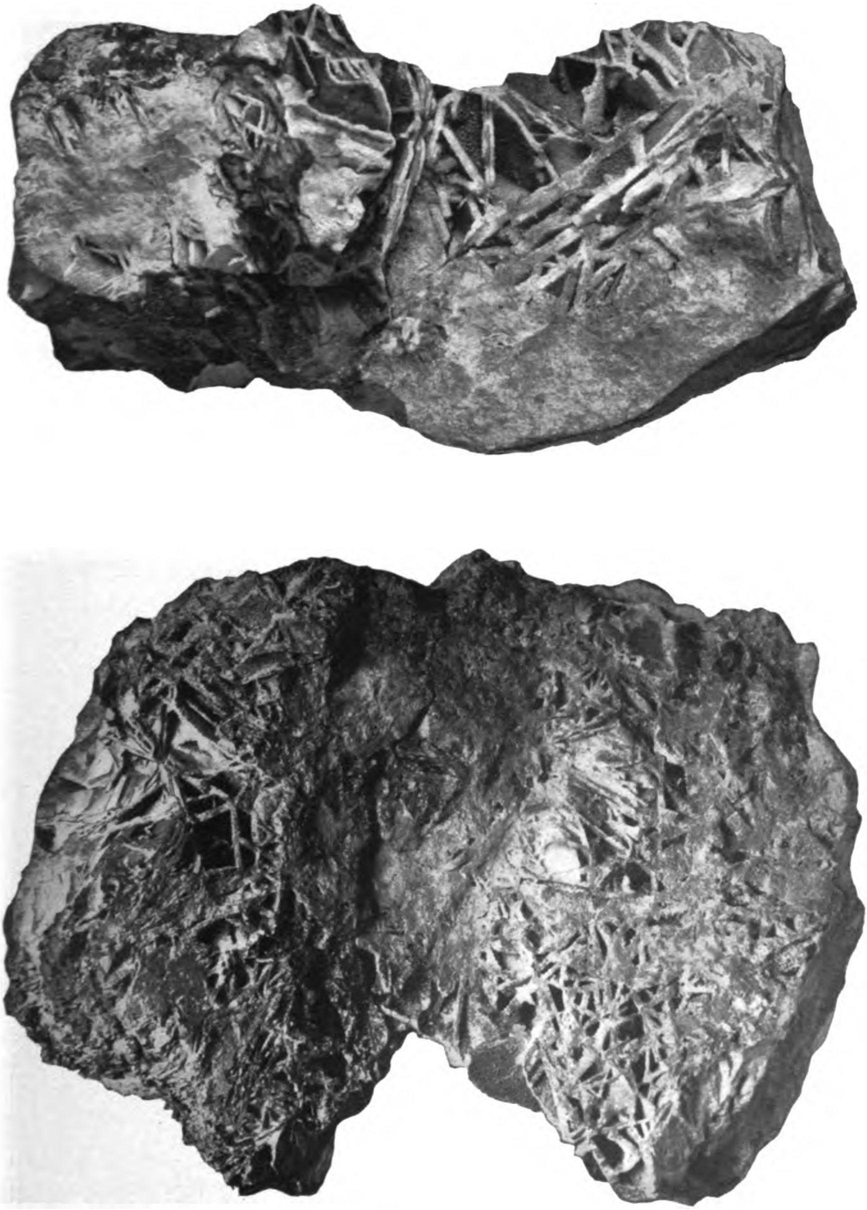
Much of the pseudomorphic platy and cellular structure seems to be due to silicification and replacement of calcite. This replacement begins along the cleavage planes of the primary calcite.

The plates range from minute size up to nearly an inch in diameter and from the thickness of a knife blade to that of ordinary pasteboard. They are mostly triangular in outline and form tetrahedral or polyhedral cavities (Pl. VIII). They are composed of fine-grained quartz and adularia. Usually each plate is bipartite or composed of two dissimilar-sided halves smoothly placed back to back against each other along a very fine median seam, from which as a starting plane the formation or mineral growth of each half proceeded outward. Each half shows one or more, usually several, layers of mineral growth, and the outer or last growth incrusts or faces the plate with a sheet of small comby quartz and adularia crystals. The seams along which the growth and development of the plates began appear to represent the cleavage planes of some former mineral, probably calcite, which the present gangue has replaced. In the honeycombed or cellular structure these plates, meeting one another at different angles, form small variously shaped polyhedral druses.

Depending on their form and mode of arrangement the plates give rise to solid angles and polyhedrons of many shapes and radial or fan-shaped and other pseudomorphic forms. The structures range from porous and cellular on a large scale to fine, closed, and filled or solid. The plates are marginally cemented together by material like that of which they are composed. In the closed forms this material constitutes a matrix in which the structures rest, and in places it passes laterally into fine or medium grained seemingly solid quartz-adularia gangue, in which only dim traces of the obliterated plates or structures remain.

Associated with the quartz and adularia in the gangue, notable in the veins of the west system, is also considerable fluorite, which seems to occur as a later filling. There is also some sericite, which, however, is mostly microscopic.

Only under the microscope does the proportion of quartz to adularia become apparent. Here the adularia may be differentiated from the quartz in subdued light and by its lower index of refraction. It occurs in individual crystals and grains intergrown with the quartz and only rarely shows cleavage.



PSEUDOMORPHIC QUARTZ AND ADULARIA AFTER CALCITE.

From Bourne mine. Characteristic of the veins and ores of the Jarbidge district.

The crystals occur in several forms, of which the most plentiful and characteristic seem to be small, thin tabular rhombic plates. Cuneiform and elongated or acicular crystals are also present, variously intergrown with the quartz. In one specimen from the Bourne mine the adularia is so fine grained that it seems to be amorphous or massive, being analogous to vein quartz or glass. Some crystals occur in Carlsbad twins. Some show zonal structure and some show the wavy extinction characteristic of vein quartz.

The pseudomorphic replacement structures of the quartz-adularia gangue are on the whole very interesting and complicated, and some of them are microscopically reproduced in Plate IX. The quartz and adularia are intimately intergrown with each other; the crystals and grains are arranged in various patterns, mosaic fashion, and show in places three generations of mineral growth, ranging from material with crystals one-fourth inch in maximum diameter to microcrystalline or even cryptocrystalline material. Some of the larger crystals, particularly those of adularia, seem to lie almost as phenocrysts in a groundmass of much finer microcrystalline to cryptocrystalline quartz and adularia. Some large crystals of adularia are replaced by the granular intergrowths of later adularia and quartz, the adularia being in small rhombic plates, prisms, and grains.

As seen in thin section the dominant structure is the general disposition of the minerals in sectors or long fan-shaped areas, each area being composed of a number of similar subareas, with the minerals in general arranged leaflike at right angles to the radii or stems and in places forming well-defined comb structure. Some thin sections of the ore show also microscopic, mostly elongated druses which are wholly or in part filled with a much finer growth of adularia than that forming the periphery, the fineness of grain commonly increasing from the periphery inward. Some druses are surrounded by as many as six more or less distinct bands of alternating coarse and fine gangue, with the crystals of the bands in part interlocking. Some druses are in part lined with the very fine grained material of the gangue; in others relatively coarse crystals, particularly of adularia, project irregularly into the druse cavities and produce a very jagged, saw-toothed lining.

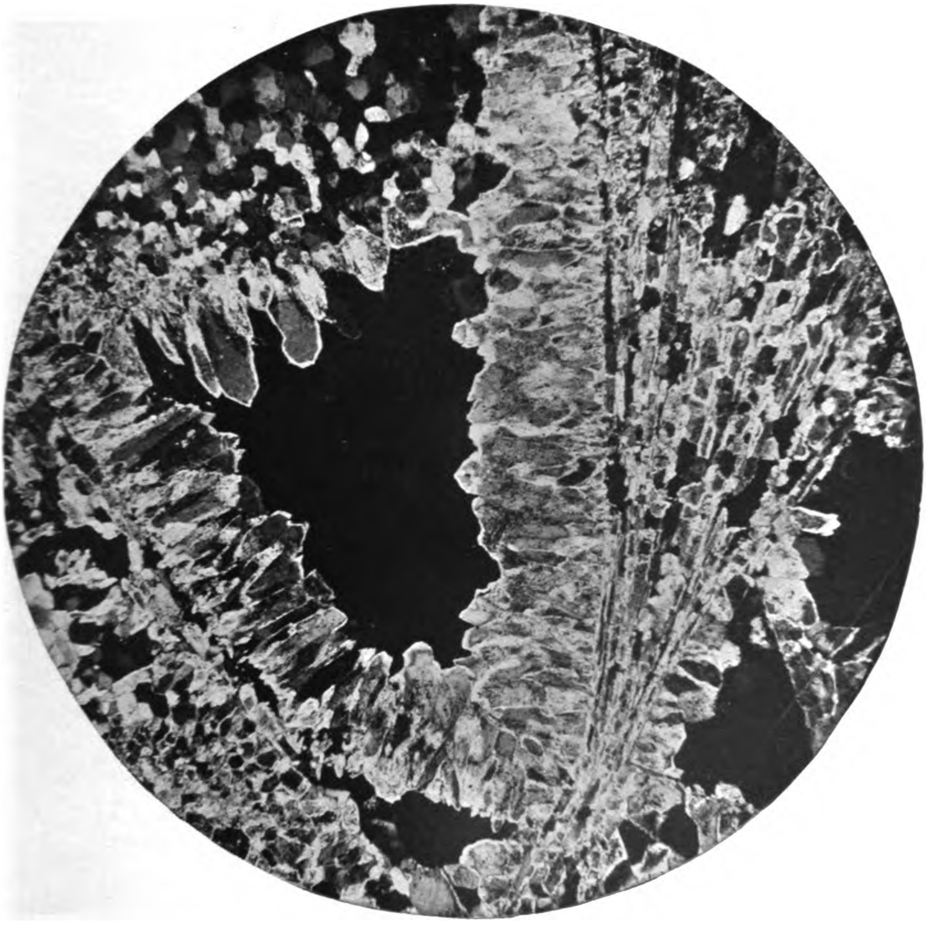
Considerable sericite, occurring mostly in aggregates and here and there in rosettes, is finely disseminated throughout some thin sections and occurs in some of the druses. Thin sections from the veins of the west system contain also considerable fluorite, which occurs mostly in the form of a late filling occupying the interstices, some of them large, between the principal gangue minerals. The persistent and plentiful association of sericite with the fluorite wherever the latter mineral is present is remarkable and not satisfactorily accounted for at present.

Disseminated generally throughout the thin sections, particularly in ores from the oxidized zones, occurs also considerable hematite as grains and dust probably derived from the oxidation of pyrite. Owing to the generally porous character of the gangue and plentiful supply of the percolating surface waters, this oxidation probably extends to considerable depths. The gangue contains also, mainly as filling, considerable gold and silver, the metals of the camp, described in detail further on. The gangue ranges from fine to coarse and from soft and friable to hard and siliceous, but owing to the prevalence of the pseudomorphic cellular structures the ore of the district on the whole is fragile and can be easily crushed and milled. It is of coarser texture and harder in the veins of the west system, where silicification has been more extensive. Here the veins are as a rule coarsely and crudely banded or massive, and the laminated gangue occurs largely in bowldery bunches up to several feet in diameter, which, however, are easily crushed. These veins also contain in places considerable fault breccia or fragments of silicified rhyolite country rock, from which it is inferred that more or less faulting accompanied the fissuring and subsequent vein formation. From the association of this silicified rhyolite the veins are often called "dikes."

Some veins, of which the Pick and Shovel is a good example, also contain fragments and seams of siliceous pale-greenish and blackish shale or slate derived from the underlying sedimentary rocks, and some contain minute parallel dikelets of rhyolite scarcely larger than a seam.

In places the walls of the western veins are irregular and ragged, or less sharply defined than in the veins of the east system, and show the most extensive propylitic alteration of the wall rock to be found in the district. Here also occur the bold croppings. Many of the outcrops are prominent reefs of the characteristically laminated quartz and adularia gangue and silicified rhyolite. They are commonly stained yellowish to reddish brown and blackish by iron and manganese.

In the eastern veins the gangue is composed of the same minerals (laminated quartz and adularia) as in the western veins, but in reverse proportions, the adularia here being the dominant mineral and constituting in the specimens examined 80 to 90 per cent of the vein. Though the same pseudomorphic structures are present in these veins as in those of the west group, they are less pronounced and the textures are relatively fine grained. The veins are closely and definitely ribboned and comby, the bands being in places separated by thin dikelets of rhyolite and by slate-colored partings.



PHOTOMICROGRAPH OF PSEUDOMORPHIC QUARTZ AND ADULARIA AFTER CALCITE.

From Pick and Shovel mine, 100-foot level. Example of the cellular, drusy, radial, and bladed structures characteristic of the Jarbidge veins. Magnified 25 diameters.

OCCURRENCE OF THE GOLD.

Both the croppings and the gangue in the veins show macroscopic free gold, the principal metal of the camp, which may be obtained by panning the crudely crushed material, the first means employed by the prospector in testing the ground. Good ground usually yields a long string of fine bright colors of gold in the pan, and rock in which the metal occurs in workable amount constitutes ore.

With the gold in the veins is associated also silver, which occurs chiefly as argentite (silver sulphide, Ag_2S; see Pl. X), as an alloy with the gold, and probably also in other forms. The quantity of silver is usually small, amounting to only 2 ounces or so to the ton of ore, but in some ore as much as 90 ounces is reported. A few operators also report tellurides, such as petzite, with the richer ore, but the presence of these minerals is not known to have been verified.

In its widest distribution the gold shows as small bodies or specks, but parallel areas or slabs of the gangue, some of them larger than a man's hand, are continuously coated or plated with gold as thick as a knife blade. In other places large areas are incrusted with blebs of iron-stained quartz, freely sprinkled with specks of gold. (See Pl. XI, *A*.)

Most of the gold, however, is finely divided and not macroscopically visible. It ranges from particles the size of a pinhead down to minute specks, in which form, usually associated with dark patches or specks of argentite and hematite and probably some other silver-bearing mineral (Pl. X), it constitutes ore more or less throughout the vein. In most of the veins, however, it is concentrated in streaks or pay shoots associated with fine dark streaks of silver sulphide and iron. The values range from low to very high, the shipping ore of some veins being worth $600 to $1,000 a ton. The Bluster vein, 5 feet in width at the point reached at the time of visit, was sampled by several persons independently and said by each to average $60 a ton all the way across.

Another common form of occurrence of the gold, as shown on the Pavlak property, is in nodules or reniform lumps formed by more or less finely banded concretionary growths of the gangue, usually round an inclosed fragment of rhyolite which is generally corroded and metasomatically altered, or around a fragment of slate, as illustrated in part in Plate XI, *B*. In these kidney-shaped forms, which usually constitute very rich ore, the gold occurs mostly along the dark lines associated with the circular banding before described.

Though the gold probably on the whole favors the quartz portion of the gangue where quartz is plentiful, in many places it seems to occur independently in both quartz and adularia. Where these two gangue minerals are present in about equal amounts, as in the ores from the Bourne and the Pick and Shovel mines, the gold seems to occur in one mineral about as much as in the other, and in some of the veins of the Crater group composed almost entirely of adularia it occurs, of course, almost exclusively in the adularia. According to B. S. Butler,[1] in the Deer Lodge district, in southeastern Nevada, the yellowish adularia is regarded as the richest portion of the deposits.

With development work scarcely begun, it is too early to form an estimate of the average value of the ore for the district or even for individual veins. From the excellent surface showings, however, it seems certain that the values will compare favorably with those of similar ores in other districts—for instance, that of the De Lamar mine, Idaho, which averages $14 in gold and 4 ounces in silver to the ton.[2] This mine has been a more or less steady producer since the early sixties and by 1900 had produced about $10,000,000.

The gold in the western veins is mostly of high grade; that of the Bluster mine, which has a deep yellow color, seems to be among the best and is said to run about $20 or more to the ounce. In the eastern veins, however, the gold is mostly light colored, contains much silver alloy, and runs only about $12 to the ounce.

ORIGIN OF THE VEINS.

From the omnipresence of the characteristically laminated and other pseudomorphic structures of quartz and adularia practically composing all the veins, and even the branches and veinlets in the wall rock down to 0.1 inch in width, it seems certain that in the fissures occupied by the present veins there have been at least two distinct periods of mineralization.

After the eruption and fissuring of the early rhyolites there followed a period of mineralization which filled the present fissures with material totally different from that which now occupies them. Just what minerals composed this first filling or what metals it may have contained are not definitely known, for so far as present developments in the district extend, no trace or clue to them remains save the casts and forms shown in the pseudomorphic quartz-adularia gangue above described. From a study of these forms in connection with cabinet specimens of calcite and barite and similar deposits in other fields, notably the Silver City and De Lamar, Idaho,[2] and the

---

[1] Oral communication.

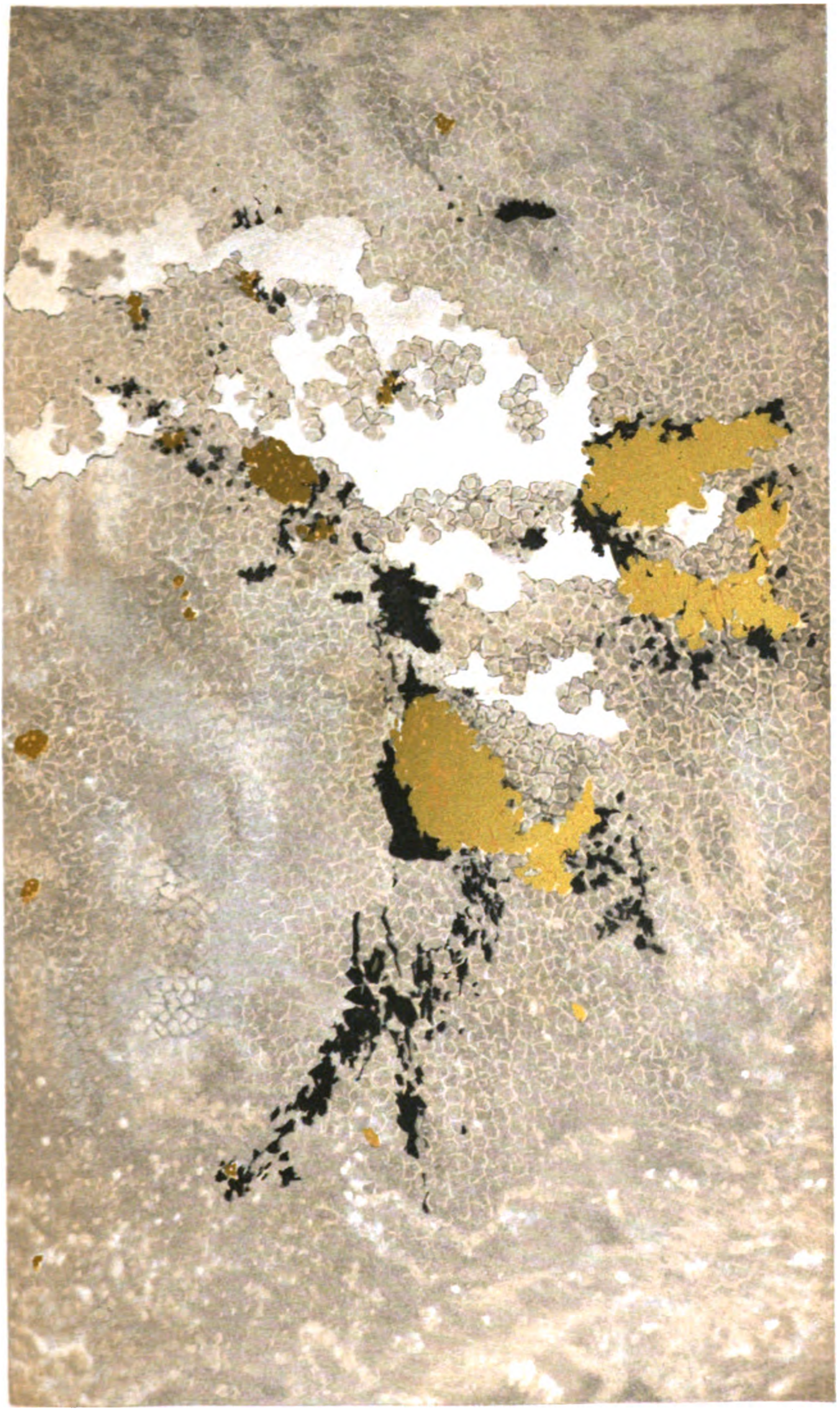
[2] Lindgren, Waldemar, The gold and silver veins of Silver City and De Lamar, Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 115.

PLATE X.

PLATE X.

PHOTOMICROGRAPH OF GOLD ORE.

From Bourne mine. Shows character and manner of distribution of the gold (yellow) in the quartz-adularia gangue (gray) and its association with argentite (black), characteristic of the Jarbidge district. The white area represents a hole in the thin section. Magnified 105 diameters.



A. HOEN & CO. BALTIMORE

PHOTOMICROGRAPH OF GOLD ORE

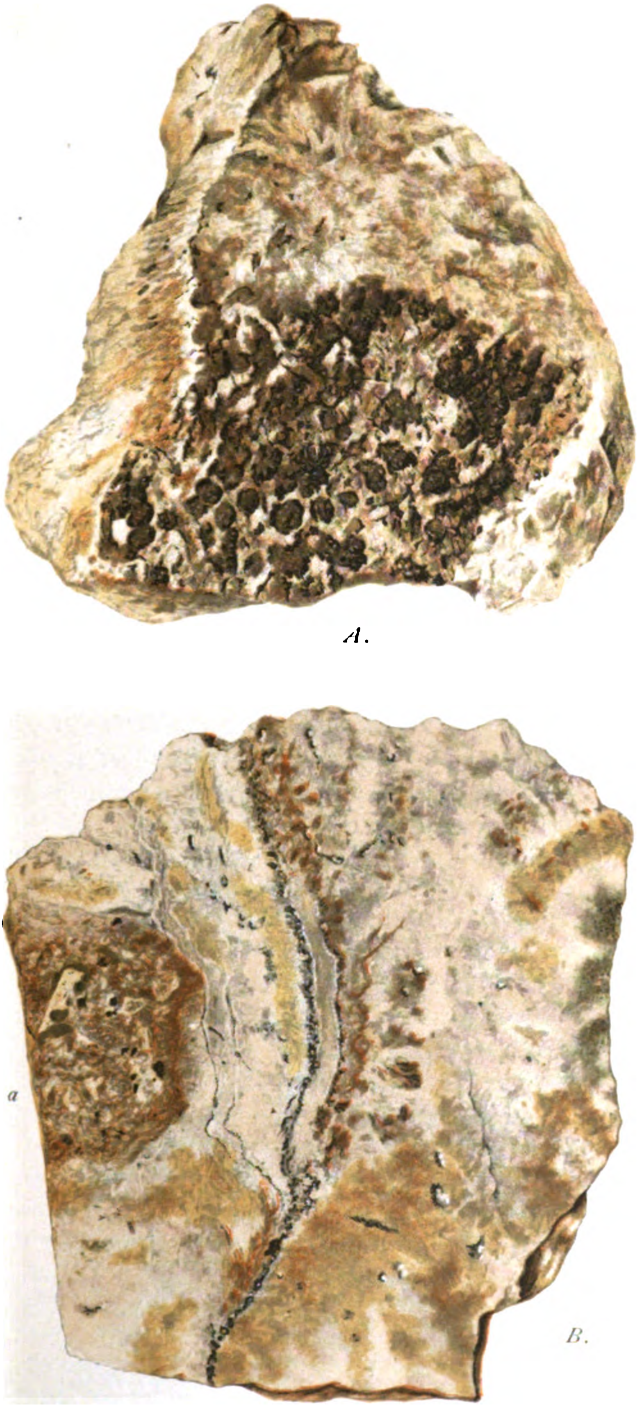
PLATE XI.

PLATE XI.

GOLD ORES.

A. " Blistery " phase, from Bluster mine.

B. Nodular or kidney phase, from Pick and Shovel mine. Characteristic of certain ores in the veins of the west system, especially the Pavlak and others. The gold occurs mostly along the dark lines and seams crudely encircling the nodular nuclei of rhyolite or other rock. The nodule marked *a* is old rhyolite that has been so corroded and metasomatically altered around the periphery by the gangue solutions that the sharp contact line has been obliterated or resolved into an ill-defined zone of transition between the vein gangue and the rhyolite.



A.Hoen & Co. Baltimore

A. GOLD ORE, "BLISTERY" PHASE
B. GOLD ORE, NODULAR OR KIDNEY PHASE

Gold Road and other districts in the Black Mountains, Arizona,[1] and with microscopic sections of ores from the Deer Lodge district and surrounding region in southeastern Nevada recently shown to the writer by B. S. Butler, it seems certain that the first minerals in the Jarbidge veins must have been calcite or barite, or possibly both, and pretty certainly not quartz. In the Black Mountain field proportionally large amounts of calcite still remain in partly replaced veins, and some large veins are still composed almost or entirely of seemingly original calcite. The sections from Deer Lodge likewise show considerable calcite, which appears to be primary. The only trace, if such it be, of these primary minerals, found in the Jarbidge district is a very little calcite which occurs here and there, seemingly as secondary filling, in some thin sections of the altered rhyolite.

The replacement of the primary minerals by the present gangue minerals, deposited first on the faces and cleavage planes of crystals and subsequently in cavities or druses, seems undoubtedly to have been accomplished through the agency of ascending hydrothermal solutions, as was first pointed out by Lindgren[2] for the deposits in the Silver City-De Lamar district, Idaho. Of the hydrothermal character of the deposition the Jarbidge veins afford plentiful evidences, among which may be mentioned the dikelets of the old lava magma, one-fourth inch or so in maximum width, filling parallel seams in the veins. The dikelets seemingly contribute nothing of value to the veins in which they occur nor do they in any wise affect them. Their manner of occurrence, however, in extremely attenuated tabular forms, together with their position at the very crest of the range, where the covering, when the veins were formed and the dikes injected, could not at most have much exceeded 2,000 feet in thickness, is regarded as significant in shedding light on the temperature that prevailed in the region at that time, for the injected magma that formed the dikelets must have been in an extremely fluidal, molten condition and possessed of great power of penetration, and this fluidity must have depended on high temperature, supplied from the plutonic seat of waning volcanism. Had the rock mass as a whole, the veins included, not been at a relatively high temperature, the progress of the magma between almost contiguous cool walls would have been quickly arrested by stiffening and congealment.

From these facts it is inferred that for a considerable period after the eruption of the old lavas, the period in which the veins were deposited the Jarbidge region maintained a relatively high though perhaps gradually descreasing temperature and the veins must therefore have been formed by ascending thermal solutions. These solutions brought in the metal values and probably contained several other minerals, but they were particularly charged with silica, potassium, and aluminum, and as they dissolved out the calcite of the original gangue, silica was precipitated and quartz intergrown with adularia was secreted in its place, largely as pseudomorphic quartz and adularia after the crystalline forms or casts of the preexisting calcite, thus forming the present gangue.

---

[1] Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Arizona: Bull. U. S. Geol. Survey No. 397, 1909.

[2] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 165–166.

In connection with the hydrothermal origin of the veins, it may be also noted that, so far as learned, the nearest hot spring to the district at present is the Wilkins Hot Spring on the Wilkins ranch, in Idaho, where the Twin Falls and Jarbidge road crosses East Fork, about 10 miles northeast of Jarbidge and a mile north of the State line.

The presence of dikes of rhyolite, particularly in the veins of the west group, suggests that some of the fissures now occupied by the veins may formerly have been occupied by dikes that have since been replaced, or that the fissures may have been reopened and vein material deposited on one or both sides of the dike, as indicated by some veins on the Pavlak property. Evidence in this direction, however, in the present stage of the field's development is not conclusive. A similar occurrence in the Eureka district, Nevada, is described by Curtis.[1]

The erroneous view that gold veins invariably become poorer with increase in depth is regarded by Lindgren as a misconception of the data involved. In describing the Ophir veins of California [2] he says:

> The veins may on the whole have been richer near the original surface, * * * but the occurrence of rich ore bodies at a depth of several thousand feet below the original surface certainly appears to indicate that the limit where gold was no longer deposited from its solutions has not by any means been reached in our present mines.

Below the water level the ore may be expected to become richer in sulphides, with probably a very material increase in silver and with the gold content mainly in the sulphides, but little if any of it being free.

The exact depth at which the Jarbidge veins were formed is difficult to say. It seems probable, however, that the veins now exposed in the upper part of the Jarbidge Mountains were formed at a depth of not more than 2,000 feet below the surface and the other deposits at perhaps a correspondingly greater depth.

ALTERATION OF WALL ROCK.

The country rock, particularly in the walls adjacent to the veins and extending for a hundred or more feet away from them, has suffered more or less extensive and characteristic alteration, in which the chief results have been devitrification and silicification of the normal rhyolite and in places the development of sericite in the feldspars as well as of much pyrite throughout the rock. This process of alteration has left the texture and constituent minerals in an almost perfect state of preservation and given to the silicified rock a fresh and unaltered appearance. Elsewhere the rock is completely replaced or changed into massize quartz or vein gangue in which all trace of the feldspars and other rock minerals has disappeared except the quartz phenocrysts, which by their wine color and other characteristics can be distinctly traced from the relatively little-altered rock over into the gangue, where they occupy the same relative position to one another which they held in the original rock.

---

[1] Curtis, J. S., The silver-lead deposits of Eureka, Nevada: Mon. U. S. Geol. Survey, vol. 7, 1884, pp. 90–106.

[2] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 279–280.

Whether some of this rock alteration may not be due to solutions of the early or primary mineralization has not yet been determined. Indications that the alteration on the whole was probably accomplished by the same solutions that replaced the veins are the absence of any sharp contact line between the present veins and the wall rock or between the vein and the inclusions of wall rock it may contain, as shown, for instance, in the specimen illustrated in Plate XI, *B*, where the passage from the vein gangue to the rhyolite is merely an ill-defined transition zone of corrosion in which the rhyolite gradually shades into the gangue, or vice versa. The rhyolite contains veinlets of quartz and adularia, which seem to be of the same age and to have been formed by the same solutions as the replacing gangue of the veins.

Furthermore, in the east-group veins that are composed chiefly of adularia, denoting that the solutions that formed them were poor in silica, there is little, if any, alteration of the wall rock. On the whole, the degree of alteration of the wall rock seems in general to bear a more or less direct ratio to the acidity of the neighboring veins.

Although, as already noted, most of the veins probably penetrate the underlying sedimentary and granitic rocks, it is also probable, to judge from the nature of the veins and the character of the rhyolites and of the fissures in which they occur, that some of the harder of these underlying rocks, such as quartzite reefs, may, like the "iron dike" in the De Lamar district, Idaho, prove to be the downward limit of certain of the veins and, by acting as a barrier and damming back their metals, greatly concentrate their values on the upper sides, a feature which should be looked into by managers planning for extensive operations. It seems also likely, as shown by Lindgren in the De Lamar district, Idaho, and already demonstrated to some extent in the Pavlak tunnel, that strong outcrops may dwindle in depth and that blind or new veins may be struck in underground work.

In veins having so-called talc seams and ore bodies in association, this material should be examined for values, for "much of the high-

e developed by the De Lamar mine, Idaho,
aracter and gave little evidence to the eye of i
ld by some that all the Jarbidge deposits of pı
o the small belt in which the outcrops or trace
s occur east of the river, and some mining men
deposits are in association with or near the q
” on either side. These views are not warrant
ns who have prospected the reef or “ dike ” repoı
no values found in it or in the quartz imme
th it, whereas in localities remote from the sedir
the north and on the south promising deposi

he sedimentary rocks, so far as they contain c
nd have come into contact with the gold-bearir
influenced the deposits is not to be doubted. T
organic and carbonaceous material contained in
nd allied rocks on the precipitation of gold is ge
nd examples of it in the Ballarat mines have be
rd[2] and in Victoria by Smyth.[3] But this influ
district, so far as present developments extend, w
e the shale partings or seams were introduced subs
rmation of the veins they could have had no influenc
tion of the gold.

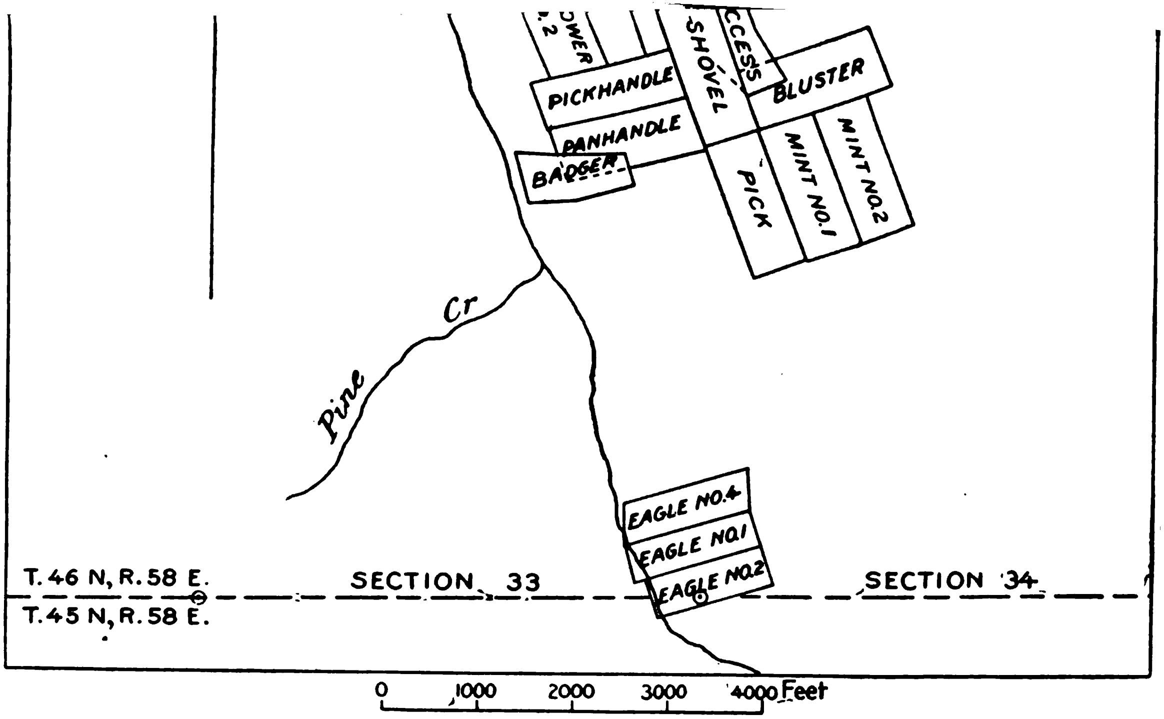
DESCRIPTION OF PROPERTIES.

ning properties of the Jarbidge district, several hun
consist as a rule of claim groups located on the vei
n described, and on most of them work has been beg
on of the more important ones must suffice to convey a
neral idea of the district as a whole. Owing to the ne
mp and the consequent incipient stage of development, a
es to lack of information owing to absence of the ov
iptions will be necessarily brief. The properties desc
ly among the surveyed claims, most of which, up to Au
shown on the claim map (Pl. XII) kindly furnishe
airbanks & O'Byrne. Plate XIII, showing about 800 cl
s, includes also unsurveyed claims and also the princ
the veins of the east system.

PROPERTIES ON THE WEST SYSTEM OF VEINS.

operties on which the most development work has been d
ne veins of the west system. They comprise the Pavl

ı, Waldemar, The gold and silver veins of Silver City, De Lamar, and ot
icts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 122.
T. A., Certain dissimilar occurrences of gold-bearing quartz: Proc. Colora
l. 4, 1893, pp. 323–329.
E. B., The gold fields and mineral districts of Victoria, London, 1869, pp. 7



MAP OF THE PRINCIPAL SURVEYED CLAIMS IN THE JARBIDGE DISTRICT.

Bourne, Buster, Pick and Shovel, Bluster, and others. On but a few of them has more than 200 feet of work been done. They are mostly located east of Jarbidge River, on the west slope of the Crater Range, in a belt about 1½ miles wide and 5 miles long, extending from the town of Jarbidge southward to the head of the river.

PAVLAK MINE.

LOCATION.

The Pavlak property, one of the earliest discoveries, is centrally situated and easy of access, on Jarbidge River about a mile above the town, between elevations of approximately 6,400 and 7,000 feet. It was located by Michael Pavlak, a leading pioneer of the camp and one of the present proprietors, late in 1909. It is owned by the Jarbidge-Pavlak Mining Co. and is operated principally by lessees. It consists of a group of about seven claims commonly known as the Arizona group, comprising the Arizona Nos. 1, 2, 3, and 4, the Amazon, the Taft, and the Rainbow Fraction. As shown in Plate XII, the claims extend for more than 6,000 feet, mainly along the Pavlak vein, in a northwest-southeast direction diagonally across the Jarbidge Valley, and outcrops occur interruptedly more or less throughout this distance. The vein seems to be in general alignment with the Pick and Shovel vein to the southeast. The principal portion of the property is on the east side of the river. Here, diagonally ascending the steep rough mountain slope, it rises 500 or 600 feet above the river, extends nearly to Bonanza Gulch on the southeast, and affords favorable ground for tunneling and mill sites.

GEOLOGY.

The country rock consists of flows belonging to the old lavas and is normal porphyritic rhyolite, except that on the Pavlak lease it includes the most altered phase encountered in the district. Much of the altered rock is purplish or bluish gray, with the feldspar kaolinized, and it is rich in macroscopic phenocrysts of wine-colored or reddish-brown "fish-eye" quartz and contains disseminated throughout considerable secondary pyrite and marcasite, both macroscopic and microscopic. It shows much secondary silicification.

The Paleozoic quartzite is reported to have been encountered recently in the Pavlak tunnel several hundred feet below the surface. The rocks as a whole are reported to show a westerly dip.

VEINS AND ORE.

There are four or more veins on the property. The most important are the Pavlak and Taft veins. They have a northwesterly strike, which is concave to the east and a steep or nearly vertical easterly dip.

The outcrops form bold reefs of silicified quartz and light-colored rhyolite stained by iron and manganese, in places as much as 60 feet wide, and rise to a height of 75 feet above the surface. The Pavlak vein is supposed to extend throughout the length of the claim group, a distance of nearly 1¼ miles. Nearly all the development work has been done on this vein. From the presence of the silicified rhyolite some portions of the vein are frequently referred to as dikes.

The Taft vein, exposed for a considerable distance along the property, principally on the Taft claim, nearly parallels the Pavlak vein on the southwest. In places it is said to show a width of 15 to 20 feet. Little development work has been done on it, but the Pavlak tunnel shows small quartz-adularia stringers which contain fair values and which are supposed to be feeders of this vein.

The veins and ore consist mainly of the gold and silver bearing quartz-adularia type of rock, which contains also much sericite widely distributed, considerable fluorite, some iron, and in places associated seams of talc from 1 inch to several inches in thickness.

The ore occurs in a great variety of forms and ranges in texture from coarse to fine and in structure from the characteristically laminated honeycombed or cellular variety rich in free gold, with gold frostings in the cavities, some yielding several thousand dollars a ton, to hard semitranslucent massive forms in which the values are usually small. A fine-grained siliceous phase showing deep-yellow free gold associated with blackish specks and streaks of a dark mineral, seemingly argentite, is reported to range as high as $4,000 to the ton. Some values occur also in the associated seams of " talc," but in a few places, if anywhere, in the wall rock.

DEVELOPMENTS AND PRODUCTION.

The development work, which was done mainly during the year 1910, consists of crosscut tunnels and drifts aggregating about 1,000 feet. They are mostly near the river at 20 feet or more above water level, on the lower west or footwall side of the veins. The work is distributed in three areas known in order from north to south as the Riddle, 4-M, and Pavlak leases, with about 100 feet on each of the two first named and the rest on the Pavlak.

4-M LEASE.

The 4-M lease, on Arizona claim No. 1, has made the best showing in the Jarbidge district so far as production and high-grade ore are concerned. On this lease, held and operated by Moffit, McCarty, Morris & Son, the principal opening at the time of visit was a 70-foot drift on the Pavlak vein, where its bold outcrops are cut by Cold Springs Gulch at an elevation of about 6,500 feet, or nearly 100 feet above the river. The drift runs S. 25° E. and has a depth or back of 120 feet at the face. The country rock is nearly normal rhyolite. It contains here and there a little pyrite, some in seams or veinlets one-eighth of an inch wide and some also disseminated through the rock, as at the Pavlak tunnel later described, but none was observed in the vein. The vein dips about 80° W.

Some of the outcrops are said to have assayed about $800 to the ton. On removal of the surface strippings on the hill slope above the drift, the vein showed a small streak of high-grade ore extending continuously for a distance of nearly 200 feet, which panned well and assayed from $300 to $850 to the ton. In the drift that was being run to open this rich ore shoot in depth the vein showed a width of 1½ to 3 feet. It consisted of iron-stained quartz and some associated rhyolitic breccia, and was practically all good milling ore worth $60 to the ton, or better. It contained also streaks, bunches, and pockets of high-grade shipping ore in which much of the gangue or matrix was sugary quartz running high in values, the highest being on the footwall side, where assays are reported to have yielded as high as $18,036 to the ton, of which 36 ounces was silver and the remainder gold. A more or less persistent streak about half an inch in width, which was being broken down on canvas and sacked for shipment, was said to range from $5,000 to $10,000 to the ton.

In some of the high-grade ore the nodular or concretionary kidney-shaped phase already described is also well developed, the streaked or banded ore being deposited concentrically around inclosed fragments of silicified rhyolite as nuclei. The encircling black streaks associated with the bands are in places rich and show free gold. The specimen shown in Plate XI, *B* (p. 62) is an example of ore of this class.

From the ore mined about 100 sacks had been hand sorted for shipment, effort being made to keep the grade up to $1,000 a ton. Late in November, 1910, it was authentically reported that from the bottom of a winze sunk to the 50-foot level drifts were being extended both to the north and to the south. A carload of shipping ore averaging $1,000 to the ton had been sacked and a large amount of high-grade milling ore was being accumulated on the dump for the new mill.

On the 4–M lease the Taft vein lies 150 feet southwest of the Pavlak vein. It varies from 8 inches to 3 feet in width and pans about $15 in free gold to the ton, but probably contains values that will average several times this amount.

A recently discovered vein on this lease, opened by a short tunnel about 40 feet below the surface, is said to show a width of about 7 feet of mainly good ore, of which about 4 feet is a fine-grained white quartz that pans well in gold and is mostly of shipping value.

RIDDLE LEASE.

The development work on the Riddle lease, held and operated by Riddle & Corrigan, on Arizona claim No. 2, includes several openings, but consists mainly of a tunnel or drift a hundred feet in length.

This tunnel starts about 20 feet above the river flats and is driven eastward, mostly in normal gray rhyolite and in part on what seems to be a spurlike vein to crosscut the main Pavlak vein, 150 feet beyond the face, beneath a shaft and bold outcrops that stud the steep slope 200 feet above the river. This work, it is said, was started on an outcrop of mostly barren quartz with which was associated an 8-inch streak of ore showing values of only about $1.60 to the ton.

The spur vein consists of the usual quartz-adularia rock and contains inclusions of metasomatically altered gray rhyolite, like the specimen shown in Plate XI, *B*. It also contains much fluorite and sericite and shows in places 5 to 8 feet of ore that averages about $15 to the ton. Here and there it carries bodies of rich ore sprinkled with visible free gold. Recent reports state that the vein has also been opened by a tunnel on a higher level, where it shows considerable quantities of $12 to $16 ore.

PAVLAK LEASE.

The Pavlak lease, also called the Pavlak-Thorout lease, is located south of the 4–M lease on the Taft and Arizona No. 1 claims and is operated by the Pavlak-Jarbidge Mining Co. It comprises some of the highest ground, strongest outcrops, and most extensive development work on the Pavlak property. The work consists principally of the Pavlak tunnel, which, starting at about 20 feet above the river flats, is driven about N. 75° E. for a distance of nearly 700 feet to crosscut the Pavlak vein at a depth of 600 feet beneath the surface. In its course the tunnel seems to have cut almost the entire Pavlak vein system. It is said to cross several stringers and two veins besides the Taft and Pavlak veins. The veins range from 2 to 8 feet in width. In the last 200 feet or more of its course the tunnel also penetrates the Paleozoic quartzite, which is said to have been encountered to the west of a vertical line beneath the shaft and the outcrops and which probably expands into the core of the mountains and perhaps widely underlies the lavas in this vicinity. In the tunnel this rock seems to deflect or pinch the veins, but near the present face of the tunnel it contains quartz stringers regarded as promising. Also in the north drift from the tunnel a large amount of good-looking quartz has been encountered on the Taft vein. Each of the four veins has been drifted on for 50 to 70 feet to the right and the left of the crosscut tunnel, with only moderate success. The best showing seems to be on the Taft vein, which, at about 80 feet in from the portal of the tunnel, shows several feet of low-grade ore.

At the east contact of the rhyolite with the quartzite there is, it is said, a large, ill-defined vein with a seam of talc and a copious flow of water, and this is thought to be the main or Pavlak vein. About 100 feet beyond this contact the tunnel crosses what seems to be a 2 to 3 foot fissure containing bowlders of hard quartz and likewise yielding a large flow of water.

The Pavlak shaft is located on the Pavlak vein on the course of the tunnel at about 600 feet above its level. It is 40 feet deep and shows the vein here to be from 10 to 12 feet wide. It was started on 2 feet of low-grade ore, but at a depth of 18 feet it shows 7 feet of ore ranging from $2 to several hundred dollars to the ton. The lower part of the shaft, 10 feet in width, is said to be wholly in good-grade milling ore, which, taken in connection with the neighboring outcrops, indicates a considerable body of good ore at this place. The entire dump from the shaft is said to pan well in gold.

About midway between the Pavlak and Taft veins a new vein has recently been opened on the surface which is probably one of those that were crosscut in the tunnel below. It is said to be 3½ feet wide and shows fair gold values. At last accounts a large body of rich ore had been opened in the crosscut from the north drift in the tunnel at a depth of about 300 feet.

The country rock on the Pavlak lease, as shown in the tunnel several hundred feet underground, is the typical porphyritic rhyolite. Though it looks relatively fresh, in reality it has undergone more alteration and silicification than any other rocks seen in the district, especially between and along the veins. In places it carries fair values. The groundmass is purple or bluish ash-gray. It is finely holocrystalline, with a tendency to be poikilitic, and it is at least partly altered by secondary silicification. Plentifully scattered throughout it are secondary pyrite, hematite, marcasite, and a little magnetite and sericite, and in places it contains much finely divided chlorite.

The rock contains abundant phenocrysts of the deep reddish-brown "fish-eye" quartz, whose cracks are filled with infiltrated hematite. Some of the phenocrysts are surrounded by aureoles of secondary silica. The orthoclase phenocrysts are in part kaolinized or suffused with secondary silica. Some contain epidote, chlorite, pyrite, and a little sericite. The principal processes of alteration in this rock are silicification, epidotization, chloritization, and pyritization.

On the bank of the river at the mouth of the tunnel the company is installing an improved cyanide plant and mill with classifiers. In November, 1910, most of the lumber and part of the machinery was on the ground. Besides treating the output of this property, the mill is planned to handle custom ore for other mines.

HAM-AND OR CURLEY LEASE.

To the south of the Pavlak lease, but on the Pavlak ground and on the extension of the Pavlak and Taft veins, is the Ham-And or Curley lease, operated by McCoy, Andrews & Murray, on which each vein is about 5 feet in width and shows milling ore that pans well. One vein is opened by a 155-foot drift and a shaft. The drift is said to show ore all the way that pans from $14 to $60 to the ton.

The shaft extends 25 feet below the level of the drift, and its bottom part is all in vein material, of which nearly 2 feet is high-grade ore and most of the rest milling ore.

PAN PROPERTY.

Joining the Pavlak property on the southeast is the Pan claim. (See Pl. XIII.) It lies mostly on the south side of Bonanza Gulch, between elevations of 6,700 and 6,900 feet. It is operated by J. P. Duncan, and is opened mainly by a tunnel or drift at an elevation of about 6,730 feet on Bonanza Gulch, which is here a canyon.

The country rock is greenish or purplish-gray hard rhyolite, and it is porphyritic mainly, with more or less conspicuous phenocrysts of the "fish-eye" quartz.

The tunnel runs S. 35° W. for about 100 feet, to a point where it obliquely strikes the vein, which trends in a southeasterly direction, like the western veins in general. The dip of the vein is about vertical, and it seems to be on the trend of the Taft vein. The vein is 3½ feet wide. It is composed chiefly of medium-textured quartz-adularia rock, some of which is sugary or fine, but inclosed in it are small fragments of completely altered and silicified rhyolite, and it presents in part a brecciated appearance. The vein is also split by a horse or lens of country-rock rhyolite about a foot in width, the extent of which was not shown at the time of visit.

The vein is oxidized and looks well, but is of low grade. The ore, which includes most of the vein, at the time of visit ran from $3 to $4 to the ton. Recent developments, however, are said to show ore of better grade in the drift about 225 feet in from the portal of the tunnel, at a depth of about 150 feet.

SUNFLOWER GROUP.

Joining the Pan property on the west and extending down Bonanza Gulch to the river flats is the Sunflower group (see Pl. XII), consisting of four or more claims owned by F. W. Riddle, which are said to comprise two veins showing workable ore of fair grade.

RED BIRD AND DUFFY CLAIMS.

On the Red Bird and Duffy claims (see Pl. XIII), joining the Pavlak property on the northeast and the Buster on the north, three veins lying about parallel with the Pavlak veins and probably belonging to the same subsystem have been opened at several points by W. W. Williams, of Butte, Mont. They are from 4 to 6 feet in width and from the outcrops seem to extend more or less continuously across the property. One of these veins for about 600 feet is said to carry nearly 5 feet of good ore that shows considerable free gold in the pan. This vein has been traced southeastward across the Guess and other groups into Bonanza Gulch.

BOURNE MINE.

LOCATION.

The Bourne property is situated about a mile north of the Pavlak mine and about three-fourths of a mile south-southeast of Jarbidge, east of Jarbidge River, on Bourne Gulch. It comprises 17 claims, known as the North Star or Bourne group, which, as shown on Plate XII (p. 66), extend more than 1½ miles eastward from the river up the steep but not generally rugged mountain slope to the 9,000-foot contour. The mine proper is situated in the western part of the group on the North Star No. 3 claim, at an elevation of about 6,950 feet, or 650 feet above the river.

The property was discovered and located August 19, 1909, by D. A. Bourne, the pioneer discoverer of the district. Soon afterward the North Star Mining & Milling Co., of Boise, Idaho, the present owner, was organized to develop the property. Development work is mostly carried on by lessees.

DEVELOPMENTS.

The developments, which consist of 100 feet or more of underground work, are mostly at the Bourne mine or Fletcher lease and at the Buys-Riddle lease.

At the Fletcher lease, held and operated by Clark & Fletcher, of Ely, Nev., the development consists principally of two tunnels or drifts driven on or in association with the lode known as the Bourne vein (see fig. 2, p. 49) and spaced 105 feet apart vertically and about 20 feet horizontally. Of these the upper or main tunnel, which runs in general in a southeasterly direction, is 212 feet long and contains about 300 feet of crosscuts and laterals, a 45-foot upraise to the surface, and a 30-foot winze. The lower tunnel, in which work is now going on, has a length of about 200 feet. It also contains a crosscut, from which an upraise is being driven on the vein to connect with the winze of the upper tunnel. This connection will give the mine good ventilation and will open considerable stoping ground. According to recent accounts this lease has been sold to a Salt Lake company by which a mill is soon to be installed.

In the Buys-Riddle lease, on the adjoining North Star claim and North Star vein, to the east, about 200 feet lower than the Fletcher lease, the developments consist of two short tunnels or drifts. The upper and more important runs S. 22° E. and is in 40 feet on the vein, which in places is about 7 feet in width, and has an 18-foot winze sunk about 15 feet in from the portal. At the time of visit a new and shorter tunnel was also being driven lower down the slope.

GEOLOGY.

The country rock consists mainly of the old rhyolite, much of which, owing to the steepness of the slope, is covered by slides and talus. The reef or "dike" of Paleozoic quartzite, about 200 feet wide, best exposed where it crosses Bourne Gulch, extends diagonally across the property in a northeast-southwest direction. No values to speak of have yet been found in association with this rock.

VEINS AND ORES.

The deposits on the Bourne group, so far as observed, seem in large part to be more in the nature of composite veins or lodes than of well-defined individual veins. They are marked by strong outcrops trending in the usual northwest-southeast direction, which, however, occur only interruptedly in isolated knobs, bunches, or masses a few hundred feet or less in extent. Though some of them are in alignment, the continuity or discontinuity of the deposits from one outcrop to another is masked by the heavy sheet of slide and talus that in most places blankets the slope.

At the Bourne mine, on the Fletcher lease, the outcrops, which are 40 feet or more wide, extend for about 200 feet, and rise boldly about 20 feet above the surface, consist mainly of silicified rhyolite and some associated vein material and contain in places very high values. Beneath the outcrops the deposit, which seems to be a lode or mineralized shear zone in highly altered rhyolite, dips eastward, into the range, at angles of 80° to 85°. The lode has an average width of 16 to 20 feet and a known maximum width of 113 feet. It is composed of the usual laminated quartz-adularia rock shown in Plate VIII (p. 54) and is said to run about $12 in gold to the ton. It shows considerable free gold in places, and free gold may usually be obtained in panning. The entire mass is deeply oxidized or stained by iron and manganese and contains seams of "talc."

Under the microscope the thin sections show that the lode material contains more than 60 per cent of adularia and is on the whole much finer grained than any seen elsewhere in the district. At least two generations of crystals seem to be present, the medium or coarse and the very fine grained. In the latter, almost as in a groundmass, the coarser crystals seem to rest, the whole forming a faintly and imperfectly banded structure, as shown in Plate IX (p. 56). In this rock the gold occurs mostly in association with argentite and in the form of free gold, as shown in Plates X (p. 60) and XI, *B* (p. 62), and described more in detail on page 57.

The gold and especially the associated argentite occur in irregular ragged-edged areas and in small bodies and grains, and the argentite also in still smaller grains ranging down to dust in the adularia interstices. Where the gold occurs in areas or specks of any considerable size it is for the most part surrounded by argentite, with which its main contact is usually irregular, as shown in Plate X.

Argentite and apparently some gold fill certain of the cracks that cross the large crystals. Some crystals or grains of adularia penetrate the periphery of the gold-bearing part of the ore and show that the gold occurs as filling and was probably deposited later than the adularia. In places the gold tends to occur in or close to the druses that are more or less surrounded by coarse adularia crystals, and some of it is associated with iron.

In the early stages of the mine's development a number of assays made by F. V. Bodfish,[1] who sampled the lode, showed that the ore averaged about 0.44 ounce of gold and 1.4 ounces of silver to the ton. Later developments show the ore in general to contain more nearly an ounce of gold and half an ounce of silver to the ton. The silver seems to occur principally as argentite.

The values favor the footwall. Here, at about 6 feet from the side of the lode, a band of ore 16 to 24 inches wide, starting about 12 feet in from the portal of the tunnel and having a known extent of 16 feet, contains more than $100 to the ton, with portions ranging as high as $10,000. The values in the winze are said to range from $16.50 to $482 to the ton. The highest-grade ore is usually associated with dark longitudinal streaks and specks of silver sulphide or argentite.

At about 112 feet in from the portal the tunnel is crossed by a northwestward-dipping fault which disturbs the constancy in values, locally terminates the bold surface outcrops overhead, and suggests that the exploited portion of the lode may be faulted down from the rich outcrops occurring considerably higher up the mountains, some 500 or 600 feet to the southeast. The adjoining open test cuts, however, are too shallow to show the dip. In the bottom of the winze is a so-called cross bar of rhyolite, which, however, may be only a horse.

According to advices received in April, 1911, the ore chute had just been opened with good results at three points 60, 100, and 140 feet below the surface, and the vein was found to vary from 8 to 13 feet in width. It showed much easy-milling $17 ore, sufficient, it is said, to run a 10-stamp mill for a year. The workings were all in the laminated quartz, said to carry the best values.

In July, 1911, it was reported that the mine had $150,000 worth of ore blocked out, and that the mill being installed on the ground was nearly completed. In this mill, it is said, the crushing will be done by rollers and the pulp passed over plates and then cyanided.

The crude alignment of the Bourne mine deposits here described with the prominently outcropping lode or reef of reddish altered mineralized rhyolite about one-eighth of a mile to the north-northwest, in the north cliff of Bourne Gulch, suggests that beneath the surface covering the deposits may be continuous between these two outcrops. At the latter locality, which is an earlier discovery, some development work has been done. The outcrops are traversed by a prominent sheetlike structure with a N. 60° W. strike and a dip of 80° S.

---

[1] Scott, W. A., Jarbidge, Nevada: Min. and Sci. Press, Apr. 30, 1910, p. 614.

On the Buys-Riddle lease the vein is in places about 7 feet wide. It is said to pan well in free gold and the ore runs about $10 to the ton, with a little high-grade ore in spots. Considerable free-milling ore containing $17 to the ton was taken out of the winze, mostly in a sugary quartz gangue.

MISSMO GROUP.

To the northeast of the Bourne property, above the quartzite reef, much of the surface dirt pans well in free gold and here a considerable area covered by the Missmo group of claims (see Pl. XII, p. 66) is being opened by a crosscut tunnel driven by E. Fletcher and others, of Boise.

BUSTER MINE.

The Buster mine is situated between the Pavlak and Bourne mines, at the foot of the mountain on the east side of Jarbidge River, about three-fourths of a mile above Jarbidge, at an elevation of about 6,360 feet, and is opened at about 20 feet above the river. It was located late in 1909 and is owned and operated by the Buster Mining Co., of Jarbidge. The property comprises several claims and a fraction (Pl. XIII, p. 66) situated on the steep hillside slope shown in Plate VII, *A* (p. 50). The country rock is the old rhyolite. Much of it is considerably altered and locally silicified along the veins and in places contains finely disseminated pyrite.

The mine is on the cross-vein system, which trends in a northeast-southwest direction, nearly across the general trend of the neighboring veins of the west system.

The deposits comprise several short parallel veins or lodes, all dipping steeply to the southeast. They are composed chiefly of the usual laminated quartz and adularia and contain in places considerable associated altered rhyolite. Of these veins the most important is a vein about 12 feet in width, with casing and slickensiding on either wall, contained in a lode 30 feet wide, whose outcrops, consisting of silicified gangue and altered rhyolite rising boldly 30 feet or more above the surface, extend for about 600 feet up the slope, as shown in Plate VII, *A*, and assay fair values in gold.

The property is opened by a 125-foot crosscut tunnel which runs southeast and crosses three veins. The first vein, located 25 feet in from the portal, is about 9 feet in width, including considerable altered rhyolite, and is said to average about $16 in gold to the ton.

The second vein, which occurs about 50 feet in from the portal, has a width of about 2 feet and is reported to carry good values. Here small bodies of the wall rock contain disseminated fine-grained secondary pyrite.

The third or main vein, the one marked by the strong outcrops and but recently reached underground, lies near the face of the tunnel, about 125 feet in from the portal, at a depth of 140 feet. It is said to be 12 feet wide and to average $12 in gold to the ton.

The continuation of this vein, or its fault fissure, is represented on the opposite or west side of the Jarbidge Valley by the Jarbidge Cave, described on page 37, which is on the strike of this vein and is roofed or capped by outcrops similar to those at the Buster mine. Within the cave are good slickensided walls on the northwest. It contains rhyolite fault breccia and associated mineralized rock or vein material and in places has yielded the prospector as high as $17 to the ton.

It seems also probable that the Amazon vein, situated to the south of the cave, formerly belonged to the main Buster vein, which it parallels and from which it seems to have been displaced by a transverse fault with a lateral throw of about 500 feet.

A 3-stamp mill being installed at the Buster mine is expected to be soon in operation. Recently a good opening has been made on the Buckeye ground, adjoining the east end of the Buster on the south and lying in the trend of the Bourne and Buster mines.

PICK AND SHOVEL MINE.

The Pick and Shovel mine, also known as the Escalon mine, is located 2¼ miles south-southeast of Jarbidge, on the middle west slope of the Crater Range, near the head of Pick and Shovel Gulch, at an elevation of about 7,600 feet, or 900 feet above the river. The camp is on the opposite or east side of the gulch, about 300 feet below the mine. The mine was discovered September 15, 1909, by John Escalon, of Elko, Nev., soon after the famous Pavlak and Bourne properties were discovered.

At the time of the writer's visit the property was developed by a 100-foot shaft sunk on the vein with a 20-foot crosscut and a 40-foot drift on the 50-foot level, a 16-foot crosscut on the 100-foot level, and 50 feet of main adit tunnel started in the hillside on a level 200 feet below the collar of the shaft. Hoisting machinery and boiler were soon to be installed. The mine is said to be bonded since March, 1910, for $100,000 to the Twin Falls-Jarbidge Development Co., with headquarters at Twin Falls, Idaho, by which it is operated.

The property consists mainly of the Pick and Shovel and the Shovel Fraction claims, shown on Plate XII (p. 66). It trends northwest and southeast, about parallel with the veins of the west system, and lies mainly between elevations of 7,300 and 7,700 feet. The slope is steep, about 30°, but the topography is not rugged. The mine is now reached by trail, but a good wagon road could readily be constructed.

The country rock is mainly the old rhyolite, which in places, especially on the north, is worn through by erosion to the underlying sedimentary rocks, notably siliceous shale and sandstone or quartzite, and some of which occurs in the mine associated with the vein. The rhyolite is normal, but is finer grained than the relatively coarse porphyritic phase occurring at the Pavlak tunnel. The bedrock is mostly covered, however, by a surface sheet of slide and talus that lies upon the slope, as shown in Plate VII, *B* (p. 50).

The deposits occur in a fissure vein or lode known as the Pick and Shovel vein. The course of the vein obliquely along the mountain side is marked in places by bold outcrops rising 30 feet or more above the surface, both north and south of the mine. The outcrops consist of the usual quartz-adularia gangue and rhyolite.

The general alignment of the vein with the Pavlak vein on the northwest has been noted in the description of the Pavlak mine. Openings on the south, near Gorge Gulch, on the Good Luck claim, and on the Free Gold No. 4 claim, are also in alignment and thought to be on the extension of the Pick and Shovel vein.

According to latest reports the vein on the 100-foot level shows a width of about 30 feet, most of which carries good average values and contains some high-grade ore, samples containing $45 in gold to the ton being reported. The high-grade ore occurs largely in dark-colored bands, streaks, or lines which, in the deeper part of the mine, traverse a relatively fresh-looking milky-white to semitranslucent rock. The dark color in these streaks and lines is due in part to argentite associated with the gold, and in part to the gangue itself, which is of dull-grayish luster and darker and later than the surrounding rock whose fractures it fills. Considerable portions of this earlier rock are almost completely replaced rhyolite.

The walls of open or loosely filled portions of fissures in the lode are faced with a reddish to brownish-gray incrustation of argentite and hematite from 0.05 to 0.1 inch in thickness, throughout which visible free gold is finely disseminated.

The ore also contains nodular concretionary forms in which fragments of altered silicified rhyolite or of the sedimentary rock are the nuclei around which deposition and ore concentration have taken place. Plate XI, *B* (p. 62), is a reproduction of a sample of the ore with rhyolite nucleus from the 100-foot level.

The ore on the whole consists of the usual gold and silver bearing quartz-adularia rock. It is for the most part crudely banded or massive and contains fragments of rhyolite and siliceous greenish-gray and black massive shale or slate ranging up to 2 inches or more in diameter, the latter being traversed by numerous quartz-adularia veinlets. Some pieces show pronounced contact metamorphism and some have been so suffused, silicified, and changed by the gangue solutions that they are altered into a kind of hard, dense aphanitic hornstone or flint. These hard flints or hornstones and the metamorphic fragments alike show finely disseminated specks of free gold.

Under the microscope thin sections of the ore, notably from the 70-foot level, show the rock to be composed of about 50 per cent of adularia variously intergrown with the quartz, all showing very complicated replacement structures, bladed, fan-shaped, and drusy, some of which are reproduced in Plate IX (p. 56). The quartz and adularia seem to be of several generations, small crystals of the older being contained as inclusions in crystals of the younger.

Disseminated throughout the ore is also considerable sericite, which occurs mostly in aggregates, locally in the druses. Fluorite as a late filling is present in considerable amount, notably in sections from the 70-foot level, and the ore contains also considerable disseminated hematite or ferric oxide in grains and dust.

Toward Bonanza Gulch on the north end of the property, at an elevation of about 7,550 feet, a 10-foot open cut shows what seems to be a lode or vein, striking N. 35° W. with nearly vertical but variant dip, which is thought to be the Pick and Shovel vein. The northeast side of this vein is composed of quartz and adularia and the remaining 8 or 10 feet is in the main partly altered silicified rhyolite, in part replaced by the same gangue minerals. The northeast wall is well frozen to the country rock. The vein is good looking so far as exposed. The outcrops are massive iron-stained quartz and silicified rock.

A short distance to the north of this opening, down the south slope of Bonanza Gulch, are exposures of the younger Paleozoic sedimentary rocks, to which the fragments contained in and associated with the Pick and Shovel vein are very similar and from which they have doubtless been derived. To judge from the amount and size of the fragments and the angular character of many of them, the parent beds probably lie at no great depth below the bottom of the Pick and Shovel mine.

From these conditions it is inferred that this mine, as well as the Pavlak crosscut tunnel, promises to disclose at an early date very interesting and significant results concerning the continuity and behavior of the veins in the sedimentary formations that underlie the rhyolite lavas, in which alone, up to the present time, the veins are known to occur. The sedimentary rocks of the Pick and Shovel mine appear different from and younger than the hard quartzite encountered in the Pavlak tunnel.

BLUSTER MINE.

The Bluster mine, also known as the Winkler mine, is situated about 2½ miles south-southeast of Jarbidge, on the middle west slope of the Crater Range at the head of Pick and Shovel Gulch (Pl. VII, *B*, p. 50), about one-fifth of a mile east of and up the slope from the Pick and Shovel mine. (See Pls. XII and XIII, p. 66.) It lies at an elevation of about 8,050 feet, or about 1,300 feet above the river.

The property consists principally of the Bluster and Scenic claims. It was discovered and located January 11, 1910, by George Winkler, T. B. Beadle, and Edward Benane, the present owners and operators, and received its name from the atmospheric conditions of the day on which it was located. Its promising character and rich ore, however, were not recognized until early in July, since when excellent results have been shown, considering the moderate amount of development. It was worked on a small scale until August 4, 1910, but from then until about the end of the year operations were temporarily suspended owing to litigation.

The developments at the time of visit consisted mainly of a 5 by 7 foot shaft 16 feet deep sunk on the footwall of the vein; later this shaft was deepened to 52 feet. The mine is now reached by trail. The topography is similar to that of the Pick and Shovel ground shown in Plate VII, *B*, except that being higher up the slope the surface is steeper and in places strewn with heavy talus and rock débris.

The country rock is the old rhyolite and is the medium or fine grained phase. It is mostly light gray and is silicified and traversed by quartz-adularia seams and veinlets, but ranges in color to dark purple or blackish.

There are no strong outcrops of the Bluster vein at the mine. Along its strike, however, about 1,000 feet to the north, in the south slope of Bonanza Gulch, outcrops occur, and farther down the slope, crossing Bonanza Gulch at an elevation of about 6,200 feet, about 2,000 feet distant from the mine, is a boldly outcropping reef or dike about 100 feet wide, commonly known as the Bluster dike. This dike is composed mainly of silicified rhyolite similar to that forming the footwall at the mine, and it is commonly regarded as representing the continuation of the Bluster vein or at least of its fissures. Several cuts or openings whose material pans well in gold have been made on or near this reef between the mine and Bonanza Gulch. The vein is also opened at a point several hundred feet to the south of the mine, on the opposite side of Pick and Shovel Gulch.

The Bluster vein as seen in the mine strikes N. 28° W. and dips 75° E., into the mountain. It showed at the time of visit a width of 4½ feet in the shaft, with both walls composed of silicified rhyolite and locally containing values.

The vein is crudely banded with five or six longitudinal bands. It is composed of the usual milky-white or vitreous quartz-adularia rock and contains some fault breccia of rhyolite and dark siliceous slate or slaty quartzite. Fragments of each of these varieties of rock form the nuclei in the nodular phase of the ore, as in the 4-M lease on the Pavlak mine and in the Pick and Shovel mine. On the whole the color of the vein is light. Much of the ore glistens with the many bright glassy faces of the small pseudomorphic plates of the gangue lying at all conceivable angles. Owing to the delicacy of these plates much of the ore is friable and is easily pulverized by rubbing between the hands or fingers. The texture is medium to fine; the coarse-textured gangue or ore such as is shown in Plate VIII (p. 54) seems to be absent.

The vein contains gold almost from the surface down. This is readily shown by panning. The values favor the footwall, and the occurrence of the metals is in most respects similar to that in the Bourne and Pavlak mines.

At the time of visit the vein in the 16-foot shaft had been carefully sampled by several persons independently, each of whom reported it to average $60 to the ton in gold and silver, including everything from wall to wall. Except about 30 sacks of shipping ore the entire dump excavated from the shaft, it is said, will average about this amount and is to be milled. In the sampling the values were found to vary in different parts of the vein. The lowest assay obtained was $10 and the highest $1,200 to the ton. The richer ore occurs in certain portions of the crude bands, mostly near the middle, on tabular slabs of quartz, where the metal incrusts areas that may reach a foot or more in diameter. A sample of this ore is shown in Plate XI, *A* (p. 62). These incrustations are richly coated or sprinkled with patches or relatively coarse specks of gold, many being from one-half to three-fourths of a millimeter in diameter. The gold seems to be coarser than that in the mines down near the river, already described.

Some of these rich bands extend continuously across the shaft and others about halfway. A 1-inch band next to the footwall is said to run $800 to the ton, and a 5 or 6 inch band next to it about $200 to the ton. In each of these bands occur thin discontinuous pay streaks running as high as several thousand dollars to the ton.

With the gold is nearly always associated considerable argentite, the quantity of which stands in direct proportion to that of the gold. The highest silver value reported from the mine is 90 ounces to the ton, which is somewhat exceptional for this district.

Since the property was released from litigation the shaft has been sunk to a depth of 52 feet, where the vein, it is said, is about 5 feet wide and is richer than at any other point at which it has been opened from the surface down.

SUCCESS GROUP.

Adjoining the Pick and Shovel and Bluster mines on the north, in the south slope of Bonanza Gulch, as shown on Plate XII (p. 66), is the Success property, owned and developed by Nelson Bros., of Nevada. It is crossed by several veins, among which that supposed to be the Pick and Shovel vein is the most important. This vein is here 5 to 6 feet in width and shows ore considerable portions of which are said to average $100 to the ton.

ROCK CREEK FRACTION AND IT CLAIMS.

Northeast of the Bluster mine and the Success group are the Rock Creek Fraction and It claims (see Pl. XIII, p. 66), traversed by a 2-foot vein composed mostly of good ore. Before the vein was opened a one-third interest in the Rock Creek Fraction, it is said, exchanged hands for $1,500.

JOSEPHINE GROUP.

On the Josephine group (see Pl. XIII), in the north side of Gorge Gulch, about half a mile south of the Bluster mine and approximately on the trend of the Bluster vein, occur two veins. The quartz in the more easterly one, which is opened by a 40-foot tunnel, is said to resemble closely that of the Bluster vein and to pan well in gold. Farther up Gorge Gulch to the northeast, on the Stray Dog, Indian Camp, and Red Rooster claims, occur two veins said to show good values and to extend southeastward across the ridge into Snowslide Gulch.

GOOD LUCK PROPERTY.

The Good Luck property is about 3 miles south-southeast of Jarbidge and about a mile south of the Pick and Shovel and Bluster mines. (See Pl. XIII, p. 66.) It is situated in the more or less steep basal slope of the mountains, mainly east of Jarbidge River, a short distance above Gorge Gulch, and lies mostly between elevations of 6,750 and 7,000 feet. It is being developed by Park & Coburn, and is opened mainly by a 100-foot drift at an elevation of about 6,900 feet, or 150 feet above the river. The country rock is the old rhyolite, for the most part considerably altered or stained reddish brown.

The deposits occur in a tabular fissure vein or lode commonly known as the Good Luck vein. It strikes about N. 10° E., with approximately vertical dip, and is from 10 to 30 feet in width. It crosses Jarbidge River obliquely just below the Scott-Power place and here shows a width of about 20 feet. Its course in general is marked by well-stained and prominent outcrops which show at the Good Luck mine, across the river in the bluff back of the Scott-Power place, on the south, and beyond Gorge Gulch, on the north. The outcrops are said to show as a rule some free gold in the pan.

The Good Luck drift follows the footwall of the vein for about 100 feet, and from its end, at about 60 feet below the surface, a lateral is turned off across the vein, which here has a width of about 25 feet. Both the drift and the crosscut show the vein to be thoroughly mineralized with finely disseminated pyrite and to contain values of $1 to $20 in gold to the ton, with some high-grade ore in places. From present indications it seems that this vein may prove to be an extensive body of low-grade ore.

ST. JOE GROUP.

The St. Joe group comprises the western part of the Free Gold group. The claims are shown on Plate XIII, but the location has been amended to conform to the trend of the vein. The property is located 3½ miles south-southeast of Jarbidge, on the extension of the Good Luck vein southward across Jarbidge River, where the vein seems to be nearly a mile long and to extend across the high interstream ridge into the head of the Fox Creek valley. It lies mainly between elevations of 6,800 and 8,000 feet in the high, narrow ridge between Jarbidge River on the east and Fox Creek on the west.

The vein has about the same course, a little east of north, that it has on the Good Luck ground. The property is owned by the St. Joe Co., of Jarbidge, and is being developed by the C. A. McMaster party. It is opened by a tunnel or drift just south of the Good Luck ground, in the base of the mountain west of the river. The tunnel has been driven for 60 feet, and, it is said, can be carried along the vein for nearly a mile, the entire length of the property, attaining a depth of 1,000 feet. It could also be used to mine the Solo vein, situated about 400 feet west of the Good Luck vein. The vein material is rhyolitic breccia and is pyritic, but in the present face of the tunnel the gangue is mainly quartz.

FREE GOLD GROUP.

The Free Gold group, comprising half a dozen or more claims, joins the Good Luck and St. Joe groups on the southeast. (See Pl. XIII.) It is owned by the Twin Falls Free Gold Mining & Milling Co., and is said to be crossed by a belt or lode 100 feet wide, the same that occurs on the Jarbidge Wonder ground near by, which is reported to pan gold at the surface throughout the extent of the property.

OZARK GROUP.

LOCATION.

The Ozark property is situated 5 miles southeast of Jarbidge, on the headwaters of Jarbidge River, where, as shown on Plate XIII, it extends in a northwesterly direction across the east branch of the river to and beyond Dry Gulch. The camp, commonly called the Foster camp, is located on the south side of the east branch, as shown in Plate III, *B* (p. 16). The property ranges in elevation from about 7,500 feet at the river to nearly 8,100 feet on the mountain slope to the north, where it crosses the ridge between Dry Gulch and the east branch.

It was located in February, 1910, by Foster & Anderson, who are the principal owners, and it is developed mainly by a few hundred feet of drifts and crosscuts.

The property lies on the rough mountain side sloping steeply to the river on the southwest, and is deeply strewn with coarse, heavy talus and slide rock.

GEOLOGY.

The country rock is the old rhyolite. It is mostly coarse, and includes flows and beds of agglomerate and breccia at a higher horizon than any of the other properties so far described.

The normal rock is more or less porphyritic, with wine-colored "fish-eye" quartz predominating over the much kaolinized feldspars. Some of its phenocrysts are nearly one-fourth inch in diameter, and the entire rock is as a rule heavily charged with reddish ferric oxide and in places contains disseminated pyrite.

The rock is cut by a N. 60° E. sheeting which dips steeply to the southeast and by a similar structure, pronounced in places, which dips in the opposite direction, at angles of about 50° NW., and in some localities seems to be or to merge with the platy flow structure of the mountain.

ORE DEPOSITS.

The deposits are contained in a fault-breccia shear zone or lode about 100 feet in width traversing the rhyolite country rock. This lode strikes about N. 17° W. It has a known extent of about a mile, and probably extends much farther. It passes beyond the limits of the Ozark property on both the north and the south, and in the latter direction it probably crosses the Great Basin divide. It is locally regarded as the southwesterly extension of the Pick and Shovel vein and is commonly referred to as the Pick and Shovel "quartzite dike." As a matter of fact, the lode shows no association or traces of quartzite or any similar rocks.

The lode stands about vertical or may dip steeply in one direction or the other. At the Foster camp, where it is crosscut to a depth of

30 feet by the river, the lode dips about 80° W. The walls are only locally well defined.

So far as shown by outcrops and openings the lode is composed mainly of crushed country-rock rhyolite or breccia, most of which is deeply oxidized and otherwise altered and in part silicified and pyritic, with the local development of laminated quartz-adularia vein material. The lode is not continuously brecciated, however, but in places contains coarse, angular blocks or masses of normal country-rock rhyolite, some of which extend nearly or quite across its width, and probably have even greater longitudinal and vertical dimensions.

In this brecciated shear zone or lode the deposits occur in bands or streaks, composed usually of altered and silicified material that is more completely brecciated than that of the lode in general, with a greater amount of quartz-adularia gangue. These bands seem to occupy fissured zones produced by differential movement of portions of the mass within the lode. In composition they differ from the lode only in showing greater concentration of mineralization. In general they lie roughly parallel with the lode, but many of them are oblique to it in both strike and dip, as shown in the Ozark mine, where some of the bands strike N. 40° W. and the lode strikes N. 17° W. They vary from 1 to 20 feet in width and usually show surface values ranging from a few dollars up to $9 or $10 to the ton. Like the main lode, they have well-defined walls in places only. They apparently favor the footwall of the lode but are not confined to it.

The property is opened at three points, which may be referred to as the south, middle, and north openings. At the south opening, where the deposits are crosscut by the river at the Foster camp, there were at the time of visit two parallel cuts, one on either side of the stream, on the footwall side of the lode. These showed moderate values. Later developments are said to show the vein or ore-bearing belt to have a width of 25 feet, to average $4 to the ton, and for several feet, in a drift now being opened, to yield $9 a ton.

The middle opening, which is the location opening on Ozark claim No. 1, is a 25-foot open cut in the hanging-wall side of the lode near the top of the ridge at an elevation of about 8,050 feet. It shows considerable mineralization and moderate values.

The north or main opening, called the Ozark mine, is toward the north end of the property at an elevation of about 7,950 feet, in the south bluff of a perennial stream gulch of steep gradient. Here the country rock is the medium to coarse grained porphyritic purple rhyolite, and the ground is opened principally by a 60-foot drift in the hanging-wall part of the lode. The drift runs 40° S. on what seems to be a contact between thoroughly oxidized normal porphyritic rhyolite on the footwall side and dark slate-colored fine-grained pyritic rhyolite that seems to be a dike on the hanging-wall side. The drift lies mainly in the footwall rock. The walls are mostly good. The hanging-wall rock is the more mineralized and contains more quartz gangue, which is said to average $7 in gold and silver to the ton. The footwall rock also contains fair values.

The ore varies in color from that of yellowish limonite to dark or blackish and though much oxidized it is more or less pyritic throughout, with the pyrite finely disseminated.

At 75 feet east of the 60-foot drift and about 35 feet higher, in the footwall side of the lode, a 25-foot drift is run on a steep eastward-dipping similar vein or band of oxidized and mineralized rock with some quartz gangue; it is 4 feet thick and is said to contain $3.50 to the ton in gold and also some silver. In fact, the Ozark ore in general is said to contain about $2 in silver to the ton.

The cross section of the lode at this place shows also three other but less important veins or mineralized bands similar to the two above described. To judge from the showing made at this place, where the lode is crosscut by the gulch, and at the Foster camp, where it is crosscut by the river, the only two places affording good exposures, it seems quite possible that the lode may be found to contain other workable deposits of low grade.

MAMMOTH CLAIM.

The Mammoth claim is said to be about a mile south of the Ozark property and to contain a 15-foot vein which seems to be similar to the Ozark and at the surface shows ore assaying from $4 to $9 to the ton.

GUESS GROUP.

The Guess property, comprising the Guess, Guess Again, Guess Fraction, Buster Brown, and other claims (see Pls. XII and XIII, p. 66), is located about 1¾ miles south-southeast of Jarbridge, higher on the mountain slope, east of the Arizona group of the Pavlak property. The topography is in part rugged and the country rock is the old rhyolite. The property is approximately on the trend of the Pick and Shovel, Bluster, Success, Rock Creek, and other veins to the southeast and is said to present good surface showings. It is being opened by a tunnel, starting on the Guess claim on the west. The tunnel is said to be in about 70 feet and to have encountered a slate formation, supposed to be the wall rock of the vein. On the Guess Fraction the company is opening a vein in the quartzite reef or "dike" (p. 66), which shows good gold colors. This vein is thought to belong to the post-Miocene deposits and is of interest in being the first of its kind reported from the sedimentary rocks in the Jarbidge district.

VULCAN GROUP.

East of the Guess group and about 1,000 feet higher on the mountain side is the Vulcan group (Pl. XIII), on which a strong vein yielding good values is said to be opened by the Jarbidge-Vulcan Mining Co.

MAHOGANY MINE.

The Mahogany mine, also known as the Tacoma group and formerly as the Blake group, comprising the Golden Eagle, Golden Queen, and fractions of each (Pl. XIII), is about half a mile west of Jarbidge, at an elevation of about 6,700 feet, or 650 feet above the river. It is in the so-called Mahogany Flats (see Pl. II, p. 12), a sort of bench in the mountain slope at the head of a short, steep gulch that trends south to Bear Creek and is traversed by the Elko mail trail. It may be reached by this trail, by a similarly steep trail from the lower part of town, or by the Elko wagon road, which begins the ascent a short distance farther down the river. The mine is owned by the Jarbidge-Tacoma Mining Co.

The topography is not rugged. The country rock is the old rhyolite, stained reddish to reddish brown. It shows considerable alteration and contains some black obsidian or glass. There are also present bands of dense white and red rocks which are probably dikes of later intrusion.

The deposits are contained in a mineralized zone, or perhaps, more correctly, a compound fault zone, several hundred feet in width. This zone contains two belts of white outcrops, each belt representing a subzone of movement, deposition, and silicification. The zone as a whole has a north-south trend. It is in alignment with and may represent the northwesterly extension of the Pavlak subvein system or its fissures, with which it seems to connect through the veins on the Valley View, Ely, and other neighboring properties. The outcrops are principally quartz and silicified white rhyolite. They dip steeply to the west and are exposed for a distance of 600 feet or more. Both belts are more or less mineralized, particularly the easterly or lower one, which is said to show values of $1 to $5 in gold for a width of 150 feet.

The deposits at the time of visit were opened by a 50-foot shaft in the slope a little below the lower belt. The shaft and dump showed mainly reddish-brown stained altered and mineralized rhyolite and associated quartz gangue or vein material. It is said to have yielded $3.50 to the ton in gold and some silver near the surface and to contain values only slightly less all the way down.

AMAZON-RAINBOW GROUP.

The Amazon-Rainbow property lies 1¼ miles south of Jarbidge, on the west side of the river. (See Pl. XIII.) The deposits are said to occur in a vein 4 feet or more in width, which seems to intersect the northwesterly extension of the Pavlak vein. Both the claims and the vein trend N. 50° E., parallel with the Buster vein on the opposite side of the river and about at right angles to those of the Pavlak property.

The property is opened by a drift on the Amazon vein. This drift in the recent part of the work is said to show about 12 feet of more or less pyritic good-looking quartz, of which 2 feet pans well in gold. In November, 1910, the drift was said to be in 90 feet, and at 100 feet farther it would strike the intersection of this vein with the Pavlak vein at 140 feet below the surface. Recent accounts state that the developments continue in good-looking quartz with the values improving and that considerable ore is being blocked out.

PROPERTIES OF THE EAST OR CRATER GROUP.

LOCATION AND GENERAL CHARACTER.

The properties of the east or Crater group are located on the veins of the east system, which have been described as occurring mostly in the upper east slope of the Crater Range. (See Pl. II, p. 12.) They are comprised in a north-south belt about 1½ miles wide and 7 miles long extending from Jack Creek on the north nearly throughout the series of "craters" to the head of Jarbidge River and the Great Basin divide on the south. They were discovered and located later than the properties of the west group, mostly late in the spring and summer after the snow disappeared from the mountains.

The veins of this group contrast more or less strongly with those of the west group in several important respects. They occupy a geologic horizon nearly 2,000 feet higher. They strike more nearly north and south and dip steeply to the west instead of to the east. They are more regular, with sharply defined, clean-cut, and usually free walls. They are more persistent and narrower, from 1 to 4 feet being a fair average width. They are closely and definitely ribboned or banded and are finer and more uniform in texture. They contain very little quartz, being so far as observed composed chiefly of adularia, and for this reason the bold silicified outcrops characteristic of the western veins are mostly lacking. There is also little of the alteration of the wall rock found to be so pronounced in the veins of the west system. The gold of the eastern veins is of a lighter color and contains much more alloy of silver.

Some of the individual veins are said to extend almost throughout the length of the belt, but lack of time precluded any attempt to follow them in this work. That some of them have an extent of 2 or 3 miles, however, seems probable.

The properties are best reached by way of Jack Creek and East Fork from the north, or by crossing the divide from the head of

Jarbidge River on the south. By a climb of nearly 5,000 feet many of the properties can be reached from Jarbidge direct, but there seems to be no record of anyone trying this route a second time.

Recently it has been reported that the True Fissure Co. and others are building a wagon road into this part of the district. This road leaves the Twin Falls road at Three Creek, follows the high lava plateau to the rim rock at a point about a mile above Robinson Hole, descends into the canyon down Robinson Creek to Robinson Hole on East Fork, and ascends East Fork and its tributaries to the several properties.

Owing to their later discovery and comparative difficulty of access they are less extensively developed than the properties of the west group, but they have been opened at many places, mostly with promising results.

The properties lie mostly in the middle 4 miles of the belt, extending from the second to the fifth "crater," inclusive, but a great deal of ground has also been staked in the northeastern part of the belt on Jack Creek.

SECOND CRATER.

In the Second, Horseshoe, or Big Crater, which is the largest of all the "craters," situated 3 miles southeast of Jarbidge at the northeast base of Jarbidge Peak, at the head of the East Fork of Jack Creek (see Pl. II, p. 12), the properties comprise the Howard-McCoy, Altitude, Van Alder, Windy, Clay, and Victoria claims or groups, among which seemingly the most important openings at the time of visit were the Howard-McCoy and the Van Elder, on adjoining claims. (See Pl. V, *B*, p. 24.) Here the first strike of high-grade ore was made in the "crater section" of the district, and in July this strike caused a rush to relocate claims.

The veins on which the Howard-McCoy and Van Alder openings are made are reported to extend from the Second to the Fifth Crater, inclusive, a distance of 4 miles, through all of which these or similar veins are opened or developed. The Howard-McCoy vein is also held by some to extend southwestward into Snowslide Gulch, opposite the Fifth Crater.

The veins lie from 120 to 150 feet apart and show fair values wherever they have been opened. At the Howard-McCoy and Van Alder mines the rock in the footwalls appears to be somewhat different from that in the hanging walls.

VAN ALDER MINE.

The Van Alder or Windy property (Pl. XIII, p. 66), owned and located by Mr. Van Alder, of Jarbidge, and operated by the Cœur d'Alene-Jarbidge Co., is located in the lower slope of the steep south rim of the "crater," about 160 feet above its floor, at an elevation of 9,900 feet (Pl. V, *B*, p. 24), and is being developed chiefly by drifting. It is on or a trifle below the contact level of a considerable body of underlying vertically jointed rhyolite with overlying horizontal massive flows.

Disseminated throughout the rock are minute crystals and grains of pyrite, to which the bright brick-red to deep reddish-brown hematite stain of the weathered surface of the rock is due.

The footwall on the east is a greenish to purplish ash gray, nearly aphanitic rhyolite with glassy base. The fault that produced the vein fissure appears to be normal, to judge from the drag or upward curving of the platy structure in the hanging wall as it nears the vein, as shown in Plate V, *B*, and figure 3.

The vein strikes N. 14° W. and dips 70° W. Where exposed at the time of visit it is 18 to 20 inches in width and is well banded, being composed of 10 or 12 distinct but not persistent bands of adularia and quartz, and some included crushed and altered rhyolite. Later reports state that in the face of the drift, which has been extended to a length of 65 feet, the vein shows a width of 4 feet and is all good ore.

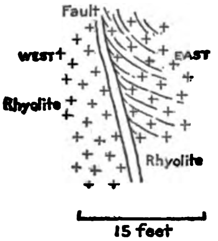


FIGURE 3.—Sketch of normal fault structure at Van Alder mine.

The vein shows a sort of comb structure, with the combs, however, usually closed up solid. Some of the crystals are nearly half an inch in length.

The west or hanging wall is the purple porphyritic to agglomeratic phase of the old rhyolite, with a glassy base having flow structure, but so closely packed with phenocrysts of altered feldspar, some nearly one-fourth of an inch in diameter, as to present the aspect of a medium-grained rock. The quartz, which is but sparingly present and occurs only in minute crystals scarcely noticeable to the unaided eye, is of the "fish-eye" type.

The vein is sharply defined, and though in sharp contact with the hanging wall it is free and has no gouge. The footwall, on the contrary, carries from 1 to 6 or 8 inches of dull-greenish gouge.

The gangue in the pure state is of light color, but owing to the abundance of hydrated iron it is deeply stained.

The vein contains a few small parallel dikelets, about one-fourth inch in maximum width, of nearly aphanitic rhyolite, one set of which is very dark purple or black and the other light purplish gray. The lighter dikelets are younger and more abundant. They cut the dark dikelets in places and inclose numerous angular fragments derived from them. These dikelets obviously belong to the magma of the old and not the young lavas and, as shown on page 63, seem to indicate that the rock mass of the region was maintained at a relatively high temperature from the first period of eruption till after the dikelets were injected, a conclusion which favors the view of the hydrothermal origin of the veins.

The vein contains also what seems to be a little dark modified slate or shale gouge, principally in parallel seams that may have been dragged up between the bands by subsequent faulting, or perhaps deposited by ascending solutions. At the time of field examination these seams were regarded as of sedimentary origin, but it is possible that closer work may show them to belong to the dikelets above described.

The vein is said to average about $30 to the ton in gold from wall to wall. According to recent reports a fair body of ore has been encountered, from which some of high grade is being sacked for shipment.

Much of the gold is finely disseminated throughout the gangue, associated with argentite and iron. Some of it also occurs as plating, but this phase is better shown in the Howard-McCoy mine, next to be described.

The microscope shows the vein to be composed of about 80 to 90 per cent of adularia, which exhibits the characteristic pseudomorphic laminated structure (Pl. IX, p. 56) more or less throughout. The adularia occurs mostly in small tabular rhombic crystals and acicular forms. Some crystals show good terminal zonal structure, and some of the larger crystals seem to be completely replaced by fine-grained granular intergrowths of secondary adularia and a little quartz. The fracture cracks traversing the thin section are filled with brown grains of limonite.

HOWARD-McCOY MINE.

The Howard-McCoy mine, located on the Altitude claim (Pl. XIII, p. 66), joins the Van Alder mine on the west, its opening being situated about 40 feet higher on the steep rim of the crater, or about 200 feet above the floor shown in Plate V, *B* (p. 24). Like the Van Alder it is developed mainly by a drift. It is owned and operated by William Connors, C. B. Howard, and J. A. McCoy.

The country rock is rhyolite, which on the hanging wall is nearly normal but conspicuously porphyritic, with "fish-eye" quartz phenocrysts. Though much iron stained, as on the hanging wall of the Van Alder vein, the rock is relatively firm and fresh. The foot-wall rock is purple or greenish gray and finer, and resembles the foot-wall of the Van Alder mine.

The vein lies 120 feet west of the Van Alder vein, which it nearly parallels. It strikes N. 22° W. and dips from 85° W. to vertical. It is regular and sharply defined, with free, clean-cut walls, and is from 1 to 3 feet in width. The vein is banded like the Van Alder vein, but not so closely, and is composed of essentially the same materials as that vein. It is iron stained, with the ferruginous material being particularly concentrated in the seams along the junctions of the banding. The vein on the whole looks well and shows much free gold, especially as sheets or plating on the faces of jaspery iron-stained bands and along the ferruginous seams. Much gold, however, is finely disseminated throughout the gangue. Argentite is also present.

VICTORIA GROUP.

The Victoria group (Pl. XIII, p. 66) is situated to the north of the Howard-McCoy and Van Alder properties, in the bottom of the "crater," at an elevation of about 9,700 feet. Here several openings have been made, principally on the Howard-McCoy vein, all showing fair values and some of them high-grade ore. The vein here is said to maintain its usual strike and dip, and has a width of 2 to 3 feet. On the Victoria No. 5 considerable ore is reported as being sacked for shipment.

CŒUR D'ALENE-JARBIDGE PROPERTY.

Another apparently promising property is that of the Cœur d'Alene-Jarbidge Gold Mining Co., on which considerable development work has been done with good results. Two ore shoots showing considerable free gold have been opened, and work by a party of 8 or 10 men, for which equipments and supplies were installed in the autumn of 1910, was carried on throughout the winter. Plans were made for soon installing a mill and cyanide plant. The principal part of the deposits is in a 4-foot quartz vein, said to carry promising values.

THIRD CRATER.

The Third Crater is located south of the Second Crater and at approximately the same elevation, with its floor at about 9,600 feet. (See Pl. II, p. 12.) It drains eastward into East Fork. In this "crater" several new veins are reported to have been discovered recently, some of which extend southwestward across the crest of the range into Snowslide Gulch, where they are marked by prominent outcrops.

The principal properties opened in or adjacent to this "crater" are the Arkansas, Rosebud, Third Peak, Rabbit Foot, and True Fissure.

ARKANSAS PROPERTY.

The Arkansas or Harder vein, on the Arkansas claim, owned and operated by R. J. Harder and Bishop Norman, is said to be opened by a 70-foot tunnel and shows several feet of ore, some of which averages about $40 to the ton. This vein is said to extend southwestward across the Arkansas, De Witt, Panorama, Laveda, High Up, Vista, and Little Mud claims into Snowslide Gulch. Where it has been opened on the Panorama the vein is said to have a width of nearly 6 feet and to consist mainly of altered rhyolitic material, with 2 feet of quartz on the footwall side.

TRUE FISSURE GROUP.

The True Fissure group, comprising five claims (Pl. XIII, p. 66), is said to extend from the upper rim of the " crater " southwestward along the crest of the range to the Third or Jumbo Peak, on whose north and east slopes it mainly lies. It is owned and operated by the True Fissure-Jarbidge Gold Mining Co. and is developed by several tunnels, drifts, and open cuts on the main or Third Peak vein, shown in figure 2 (p. 49). This vein is said to consist mainly of 2 to 7 feet of granular soft white sugary quartz between well-defined hard bluish " porphyry " walls. At the time of visit the lower drift was in more than 155 feet and was said to show good ore all the way which pans well in gold and shows some macroscopic free gold. The company has done considerable prospecting and development work on several other veins.

At last accounts this property seems to be taking rank among the best in the district. The drift has been extended to a length of 185 feet, throughout which the ore body is continuous in extent and from 2 to 6 feet in width, and the main outcrops, toward which the drift is being carried, still lie 200 feet ahead and several hundred feet above its present face. A mill is to be installed near Fall Creek below the mine, where there is a good supply of saw timber and water power, and the mine and mill are to be connected with the East Fork wagon road.

SNOWSLIDE GULCH.

On the Snowslide Gulch extension of the Arkansas and Third Peak veins from Third Crater, on the High Up, Vista, and Panorama group (Pl. XIII), Middleton & Eichert are said to have recently opened several good ore shoots. In fact, recent recognition of the fact that the projected courses of several of the Crater veins, as well as a number from the Bonanza Gulch field of the west system, trend in the direction of Snowslide Gulch, whose head is a great gash in the steep mountain side, has led to considerable staking and development work in this vicinity.

FOURTH CRATER.

The Fourth Crater lies next south of the Third Crater, at an elevation about the same or slightly lower, the upper part of its floor being crossed by the 9,200-foot contour. (See Pl. II, p. 12.) It drains northeastward into East Fork. The country rock is the old rhyolite. The principal properties near this "crater" seem to be the Sugar group and the Round Up.

SUGAR GROUP.

The Sugar group, said to consist of nine claims, is owned by Mr. McCormick and partners. The vein, which has some prominent outcrops, has been opened at several points with good results and shows free coarse gold.

ROUND UP GROUP.

The Round Up group (Pl. XIII, p. 66), on which but little work has yet been done, is said to show chiefly good milling ore.

WHITE QUARTZ VEIN.

On or near the crest of the divide, at the head of the "crater," and striking nearly north and south, parallel with the axis of the range, is the White Quartz vein. It is said to be the smallest, most perfect, and most sharply defined vein in the district. It is but 15 inches in width and is reported to extend for 2 miles or more.

FIFTH CRATER.

The Fifth Crater lies next to the Fourth Crater, on the south, at a slightly lower elevation, approximately on the 9,200-foot contour. (See Pl. II, p. 12.) It is just across the narrow divide to the east from the East Fork of Jarbidge River and is best reached by the Jarbidge River route. It drains northeastward, through Cougar Creek, into East Fork. The country rock is the old rhyolite. The veins are said to be essentially the same that occur in the Third and Fourth craters to the north. The principal property seems to be the Wall Street group, consisting of four claims. It has two openings on the vein, which is said to contain about 4 feet of mineral-bearing quartz.

Two other properties, owned by Buys & Franklin and Harder & Norman, are said to contain some high-grade ore. A good-looking vein that is said to occur in the crest of the divide at the head of the "crater" is probably the southerly extension of the White Quartz vein described above.

FIRST OR JACK CRATER.

The First or Jack Crater lies at the head of Jack Creek, north of the Second Crater, from which it is separated by a northeast-southwest ridge that is in part low and narrow. (See Pl. II, p. 12.) It is about 2 miles east-southeast of Jarbidge and is easy of access by way of Jack Creek. It has about the same elevation as the Second Crater, its floor being crossed by the 9,200-foot contour. It drains northward into Jack Creek. The country rock is the old rhyolite. The principal veins reported here are the Comet and Camp Bird, on both of which development work is being carried on with good results. The Comet property consists of a group of claims owned by Pontaine & Cameron Bros., of Jarbidge. The vein is composed chiefly of the characteristic quartz-adularia replacement gangue and shows free gold.

JACK CREEK AREA.

The Jack Creek area joins the First Crater on the north. It is a mile or more wide and extends northwestward down the curved course of Jack Creek and its East Fork for a distance of about 3½ miles to Jack Hole. The area has a vertical range of 3,000 feet, mainly between the 6,000 and 9,000 foot contours. In its upper part the topography is rugged and the main streams in part flow in canyons.

The country rock is the old rhyolite, heavily iron stained.

The deposits occur in about a dozen veins or lodes, some of which are shown in figure 2 (p. 49). They include the Big Ledge, Fissure, Idaho, Wandolee, Virginia, War Eagle, Georgian, San Felipe, Beatty, and others. They mostly strike about northwest and dip 70° SW. to 90°. They agree in dip with and are regarded as belonging to the east vein system, though they strike more nearly parallel with the west system. Some of them have a known length of nearly a mile. A number of these deposits are among the most recent discoveries of the camp. The existence of some of the veins had been known for some time, but they were not thought to contain values.

Among the properties of the area one of the most important and most developed seems to be the Big Ledge group. It comprises five claims and is located mainly on the Big Ledge vein, 2½ miles northeast of Jarbidge and about 1¼ miles up the creek in a southeasterly direction from Jack Hole, above the junction of Jack Creek and its East Fork, at an elevation of about 7,500 feet. It is owned chiefly by A. E. Bettles, of Jarbidge, by whom the deposits were discovered late in 1910, and it is developed mainly by a 40-foot tunnel or drift and terminal crosscuts.

The country rock is the old rhyolite. The vein, as shown in figure 2 (p. 49), strikes northwesterly and dips 60° to 85° SW. It has a known extent of about half a mile. It outcrops more or less prominently on the Big Ledge property for about 100 feet, and from outcrops and float found interruptedly along the projection of its course it seems to extend into the First or Jack Crater, about 2 miles to the southeast, and to connect there with the veins of the east system.

The vein is composed mainly of the laminated quartz characteristic of the district; some of it is hard and glassy. The material is said to pan well and to show some free gold.

In the principal opening on the property the vein has a reported width of 9 feet and contains several shoots of ore averaging about $30 to the ton in gold. In an open cut about 700 feet south of the main opening the vein shows a width of 7 feet and is said to average $6.50 in gold and 4 ounces in silver to the ton.

Paralleling the Big Ledge vein on the east, at a distance of 200 feet, is another vein about 6 feet in width from which samples are said to have indicated values of $9 in gold to the ton. At about 400 feet west of the Big Ledge vein the country rock is traversed by a parallel, mineralized, brecciated fault or shear zone from 10 to 20 feet in width, which is said to be very persistent and to have been traced southward into the First and Second "craters." It is composed principally of finely-crushed "conglomeratic" material or breccia, surface assays of which show values of $1 to $2 a ton. This "ledge" has not yet been opened.

Associated with the veins here described are said to be also a couple of "cross" veins, seemingly somewhat similar in occurrence to the Buster, Amazon, and others of this class on the Pavlak and Bourne properties, already described, and forming in a rough way a branching or linked system.

The ores of the Big Ledge group, as a whole, are said to be less free milling than any other ores of the Crater system.

OTHER AREAS AND PROSPECTS.

Besides the deposits which have been described there are several outlying areas in which indications of mineral are reported to be good and in which, though they are for the most part situated farther from the seat of volcanic eruption, values may reasonably be expected to occur.

On East Fork, to the east of the Crater group of veins, is a belt of country some 2 or 3 miles in width in which the indications of mineral are reported to be favorable but in which no discoveries or openings to speak of have yet been made.

This vicinity includes the eastern foothills of the Crater Range, East Fork, and the east side of its valley, in which the tributary canyons show the old rhyolites extending eastward beneath the covering of young lava.

Reports essentially similar to those on the East Fork area are also made with regard to a considerable portion of the upper south slope of the Great Basin divide, on the headwaters of Marys and Salmon rivers. (See Pl. I, p. 10.) This area, it should be noted, contains the projected course of the Crater Range, along which the ground seems particularly to commend itself for prospecting, for there is good reason to believe that the faulting or crustal deformation that permitted the outpouring of the lavas of the Crater Range extended far south of the Great Basin divide.

Values are also reported as being found at the head of Deer Creek, in the western part of the district.

A new strike was recently made on the west side of Jarbidge River just south of Pine Creek, where about 2 feet of well-mineralized quartz, contained in an 8-foot vein, is said to pan well and show free gold.

Recently several promising discoveries have been reported from the head of Bear Creek and seem to be important in confirming the extension of the deposits into the southwestern part of the district. Among the new strikes are the Mohawk vein, which is said to be a well-defined vein, about 5 feet in width, and much of which assays about $7 to the ton, mostly in gold.

In January, 1911, a strike of silver and copper ore made 8 miles southwest of Jarbidge, on Coon Creek, which drains westward into Bruneau River, was reported to be attracting considerable attention. The deposits of this strike seem obviously to belong to the early or Cretaceous group, associated with the older rocks and their granitic intrusions.

PLACER DEPOSITS.

No workable placers have yet been found in the Jarbidge district. Their apparent absence is remarkable, considering the plentifulness of the lode gold and the great depths to which the valleys are worn down into the gold-bearing veins and rocks.

Fine gold is, of course, sparingly present in practically all the recent stream gravels, but thus far the gravels have received little attention. At the time of visit the gravels were being prospected on a moderate scale on Jarbidge River, mainly at a point about 1½ miles below the town, or half a mile below the forest station, by the Park City (Utah) Placer Co. The deposits here, measured from rim rock to rim rock, have a width of about 600 feet and, as shown in the bottom of the workings, a thickness of more than 14 feet, including a 5-foot terrace on the east. They are the normal old rhyolite stream gravels described as alluvial deposits on page 33 and are opened by about 50 feet of trenches and a pit. A pan of the gravels taken from the bottom of the trench and washed by the writer gave considerable fine black sand and three colors of fine gold. The operators report that colors are found in nearly all the gravels and that the deeper strata frequently yield ten or a dozen colors to the pan, but the colors are all fine. This is encouraging, however, and leads to the hope that on bedrock the gold may be coarser and may occur in such quantities as to render the ground workable. Sinking to bedrock at this place is rendered difficult and had at the time of visit been delayed by the water of the river percolating through the gravel. The same difficulty, it is said, led to the abandonment of an attempt to prospect the gravel some years ago.

The company reports that there is an increase in the amount of gold and particularly the number of colors downstream from this place. At the mouth of Buck Creek, in the piedmont plain, some 8 or 10 miles below Jarbidge, similar gravels worked by this company often yield from 60 to 70 fine colors to the pan.

Some of the ice-laid deposits of till, or ground moraine, described under "Geology" (p. 32), may likewise be auriferous, though as yet they have received no consideration. The deposits which most commend themselves to prospectors' attention are those which have accumulated on the downstream sides of areas containing promising ore-bearing veins or lodes, of which Snowslide Gulch is an example.

To judge from the geologic history of the district, it is also quite possible that on the outskirts, particularly on the north, buried stream placers may exist beneath the young or rim-rock lava covering. Such placers were formed during the intervolcanic period of erosion and are of early Pliocene age. Except in places where they were derived from the richer portions of the surface on which the veins were first exposed, the deposits are probably similar in character and grade to the present stream deposits and were laid down on slopes of gentle gradient favorable to their accumulation.

THE CONTACT DISTRICT.

GEOGRAPHY.

LOCATION.

The Contact mining district[1] (Pls. I, p. 10; XIV) is in the northeastern part of Elko County, Nev. (see fig. 1, p. 12), about 35 miles east of the Jarbidge district. The town of Contact, the principal settlement, is near the center of the district, about 15 miles south of the Idaho State line and 40 miles west of the Utah boundary. It is 35 miles from Rogerson, the nearest railway station on the Oregon Short Line, to the north; about 50 miles from Wells, on the Southern Pacific Railroad and Western Pacific Railway, to the south; and 80 miles northeast of Elko, the county seat.

The district lies on the headwaters of Salmon River, which, taking its rise in the mountainous belt that divides the Great Basin from the Snake River plain, after doubling back on the first 20 miles of its course (see Pl. I, p. 10), flows in a northerly direction and joins the Snake at Lewis Ferry, about 50 miles north of the Idaho State line and 20 miles below Shoshone Falls.

TOPOGRAPHY AND DRAINAGE.

The district lies in the Nevada Plateau and, broadly characterized, is an elongated quaquaversal produced by the updoming of Paleozoic sedimentary rocks by an underlying intrusive granitic mass from whose intracontact area all the sedimentary rocks have been removed. The floor of the basin has been lowered by erosion to a considerable depth into the granodiorite.

The mountains are of the rounded massive type. Of these the principal landmarks are Ellen D., China, and Middle Stack mountains, situated about 8 miles apart, in the western, southern, and northeastern parts of the district, respectively, at the apices of an equilateral triangle (Pls. XIV, XV). Important secondary points are Blanchard Mountain, toward the southeast, and Toano J Peak,[1] on the east. The latter occupies a commanding position is visible from the vicinity of Rogerson and other points 50 m distant.

---

[1] Legally Contact is in the Salmon River mining district, which was organized in 1909 and extends from the eighth standard parallel, 25 miles south of Contact, range corners 62, 63, 67, and 68, 42 miles northward to the Idaho State line, having a width of 30 miles. Up to that time the country to the southeast of Salmon River was in the Kit Carson and Portis districts; for example, the Hanks-Boston property, in the northern or Middle Stack Mountain part of the Contact area, was patented and recorded in the Kit Carson district, and the southern or China Mountain portion of the Contact area lay in the Portis district; about 18 miles to the southeast of Contact began the Delano district.

These mountains are all on the Contact zone (Pl. XIV) and their existence to uplift and induration of the rocks by me morphism and silicification. Other subordinate but conspicu features are inlying flat-topped lava-capped buttes, of which Ta Mountain, near Old Contact, one like it west of San Jacinto, a similar ones on Meadow and Trout creeks are examples.

Salmon River, the master stream of the area, flows through it i northerly direction in a narrow but generally open valley floo with lake beds and gravel. This valley is from half a mile to a mi or more in width, and its sides rise in furrowed, more or less débri covered slopes which in Ellen D., China, and Middle Stack mou tains culminate, respectively, at 8,500, 8,100, and 7,900 feet above th sea, or a maximum of 3,150 feet above the valley. The rise from th river westward to the top of Ellen D. Mountain is made in a hori zontal distance of 4½ miles, or 700 feet to the mile. The grade t the top of China Mountain is about 917 feet to the mile and to th top of Middle Stack Mountain about 670 feet to the mile.

The central east-west granitic belt of the area, shown on Plate XIV, has a width of about 6 miles and a known length of 25 miles. It presents, as is shown in the foreground in Plate XV, *B*, a rough though not generally rugged adolescent topography as developed in an arid climate.

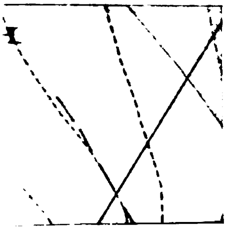
This belt seems to represent an elongated dome-shaped mass, now truncated and deeply eroded, so that in general it is below the level of the surrounding rocks. For convenience it may be referred to in this report as the basin. In fact, the rocks along the peripheral contact of the granodiorite form a more or less continuous ridge, the peaks of which constitute the highest features of the district, overlooking on the one hand the low interior basin and on the other, with gentler slope, a more elevated lava plateau. The roughest topography of the granitic area is in the southwest, between the headwaters of Meadow and Trout creeks. Here the broad ridge extending northeastward from China Mountain bristles with sharp peaks and pinnacles which are commonly known as the White Peaks and are so designated on the General Land Office map.

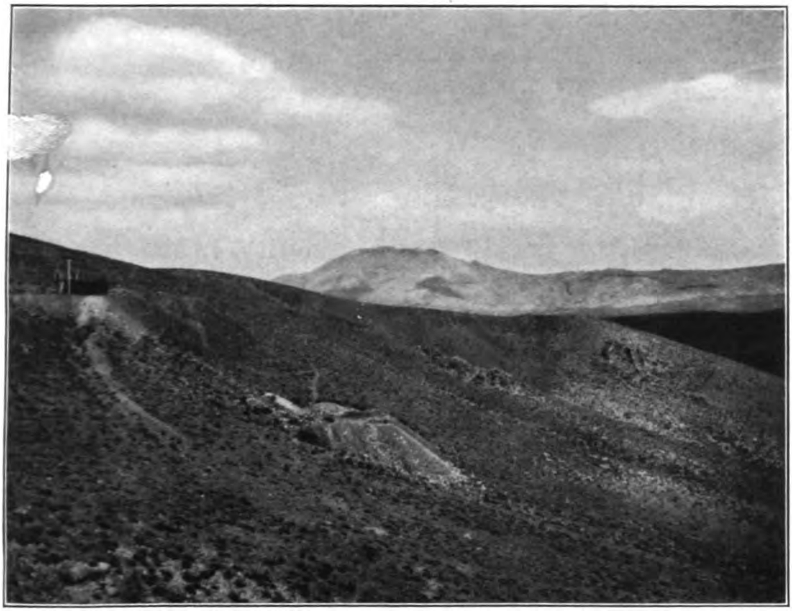
Nearly encircling the basin or central belt of granitic rocks is a zone from 1 mile to several miles wide, of hilly but gentler topography (Pl. XVI, *A*) in a quaquaversal belt of Paleozoic sediments that dip away from the basin. In places the inward-facing edges of these upturned rocks form scarps, as at China and Ellen D. moun-

---

[1] Said to be so named after an Indian chief.

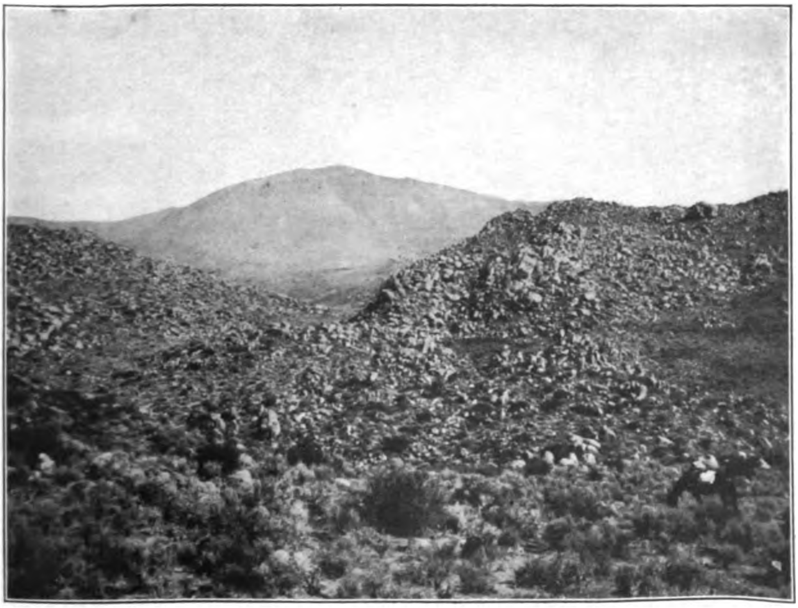
Bl





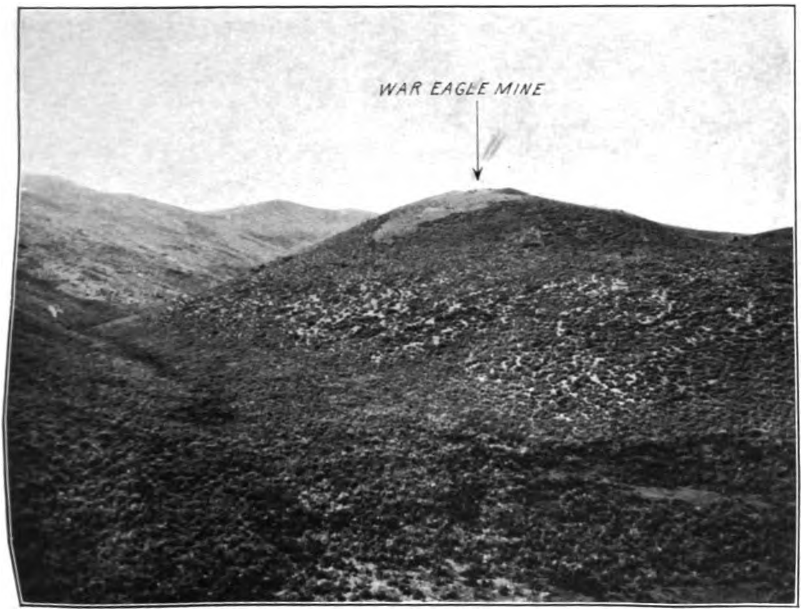
A. PALO ALTO MINE AND MIDDLE STACK MOUNTAIN.

The mine is in the left foreground with basal quartzite croppings extending to right of center; Middle Stack Mountain, 7,900 feet in elevation, is in the far center beyond Salmon River valley, with its whitish limestone contact between intrabasin granodiorite area on right and Paleozoic sedimentary rocks, forming main and higher mass of mountains, on left. View from Delano Hill.



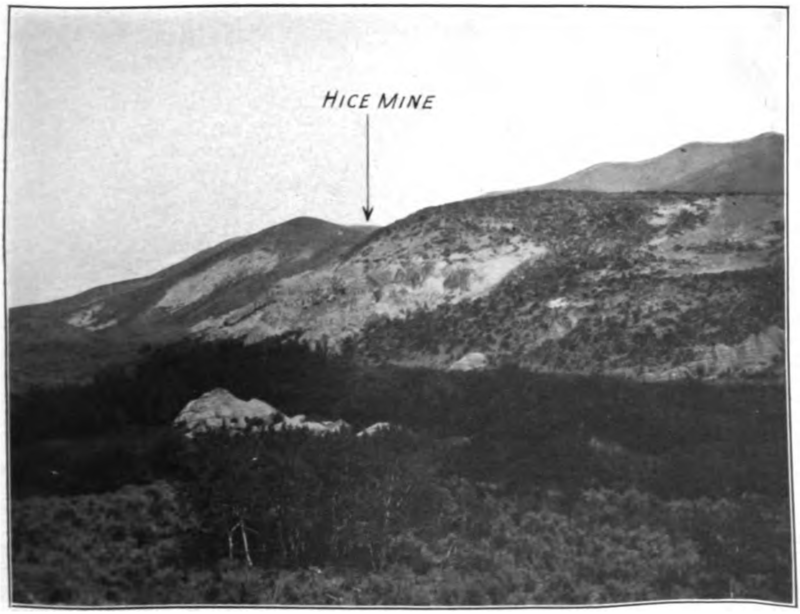
B. VIEW SHOWING TOPOGRAPHY OF GRANODIORITE BOWLDERY SURFACE AREA (IN FOREGROUND) AND ELLEN D. MOUNTAIN, 8,500 FEET IN ELEVATION (IN BACKGROUND).

From point northwest of Ivy Wilson camp, looking N. 10° W. up Thompson Gulch. The mountain is composed chiefly of Paleozoic sedimentary rocks.



A. TOPOGRAPHY IN ERODED PALEOZOIC SEDIMENTARY ROCK BELT, CHIEFLY LIMESTONE, IN CHINA MOUNTAIN AREA ON THE WAR EAGLE MINE.

Looking N. 55° W.



B. LAKE BEDS OF TUFFACEOUS SANDSTONE (HUMBOLDT FORMATION, PLIOCENE), KNOLL CREEK VALLEY.

Looking north-northeast nearly up the valley; H. D. Range, chiefly Paleozoic sedimentary rocks, in right background.

tains, but more commonly they outcrop as long, sloping ridges. In some places, as at China Mountain, the scarps are compound, their several members being surmounted by narrow dip-plane benches.

Surrounding the sedimentary zone is an area of brown rhyolitic lavas which is continuous with the Jarbidge and Elk Mountain lava field on the west and with the Snake River lava plains on the north.

The prevailing topographic forms in these lavas are benched mesas, scarps, box canyons, and sharp V-shaped gulches, depending on the local character and attitude of the flows, which are nearly horizontal or gently tilted. Inliers of these lavas also cap isolated flat-topped buttes, as at Table Mountain, just southwest of the old town of Contact.

Other subordinate features occurring in certain of the valleys are miniature badland forms carved in horizontal lake beds of whitish or light-colored soft friable "sandstone" or water-laid volcanic tuff, as on Knoll Creek, in the southeastern part of the district (Pl. XVI, *B*). The creek takes its name from the many knolls carved from this formation, some of which resemble the snow huts of an Eskimo village.

Salmon River is formed by many small tributaries whose sources lie chiefly in the southeast slope of the Elk Mountain ridge and in adjacent parts of the Jarbidge Mountains on the west. Of these the most important, beginning on the northeast, are Wilson, Lime, Pole, Cottonwood, Canyon, Camp, and Deer creeks.

At Contact the river has a nearly graded course. It flows in a shallow channel sunk only a few feet below the general surface of the valley and is said to carry 5,000 miner's inches of water at its lowest stage. In the southwestern part of the district the river is joined by Jake Creek, which, with its tributary, Knoll Creek, drains the south-central part of the district. In its course through the middle part of the district the river receives the drainage of several gulches, most of which are dry during the summer. They are Thompson, Bluejay, and Town[1] gulches on the west and McDuffy Gulch and Meadow Creek on the east. They all lie in the granitic area, which is liberally dotted with excellent small springs of water.

About a mile north of San Jacinto the river is joined by Trout Creek, an important tributary, which, rising on the southwest near the crest of the Great Basin divide, drains the eastern part of the area.

CLIMATE.

The climate is broadly similar to that of other upland districts in the Great Basin region near the Snake River valley. Although more arid it otherwise differs but little from that of the Jarbidge district.

---

[1] As this gulch seems to be unnamed, it is here called Town Gulch, from the fact that the old, the new, and the lower towns of Contact are located on it.

It is nearly rainless, with only a moderate snowfall in winter, much less than occurs in the Jarbidge district. The summers are long but not hot, though there is a great daily temperature range during the midsummer months. In the mountains frost may occur on almost any night in the year.

VEGETATION.

The region, as shown in Plates XVI, *A*, and XVII, is for the most part a treeless desert covered with a scattered growth of sagebrush, scrub oak, mahogany, and other shrubs. Fair growths of willow and cottonwood flourish along Salmon River and the larger creeks and forage grass grows in the valleys and on favorable slopes, especially in the granitic belt. The river flats are utilized for grazing and the raising of hay.

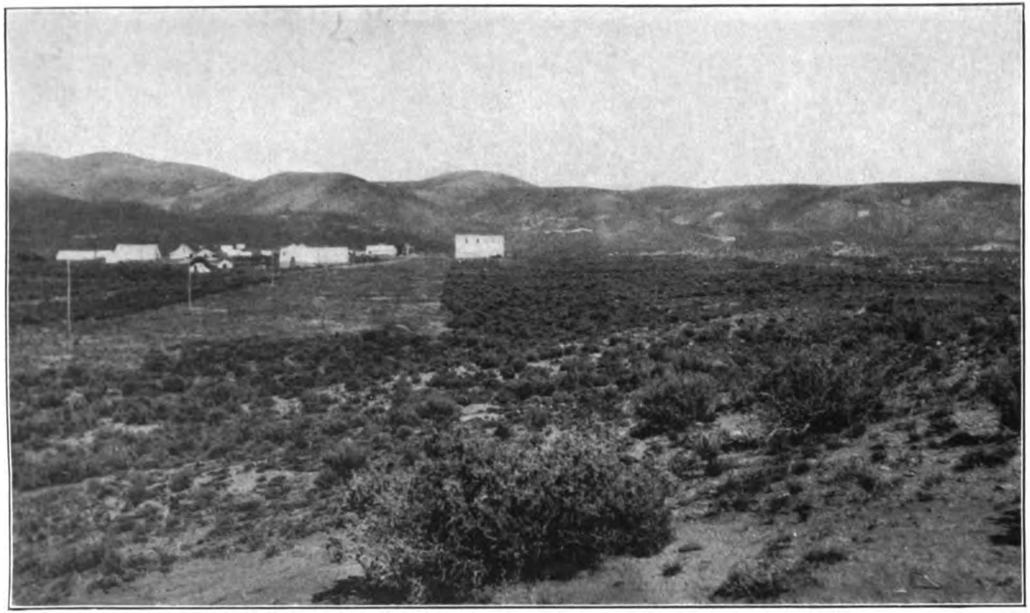
HISTORY AND PRESENT CONDITIONS.

Complete records of the district are not available. In 1897 an old claim notice dated 1870 and signed James Moran was found by W. T. McArdle inscribed on a monument on the north contact belt east of the river, from which it is probable that indications of ore were found prior to that date. The early prospecting up to the middle seventies was solely for gold.

In 1876 the China Mountain deposits were located by an official of the Southern Pacific Co., who enlisted the services of three parties of Chinamen on commission and sunk several 50-foot shafts in search of copper, with encouraging results.

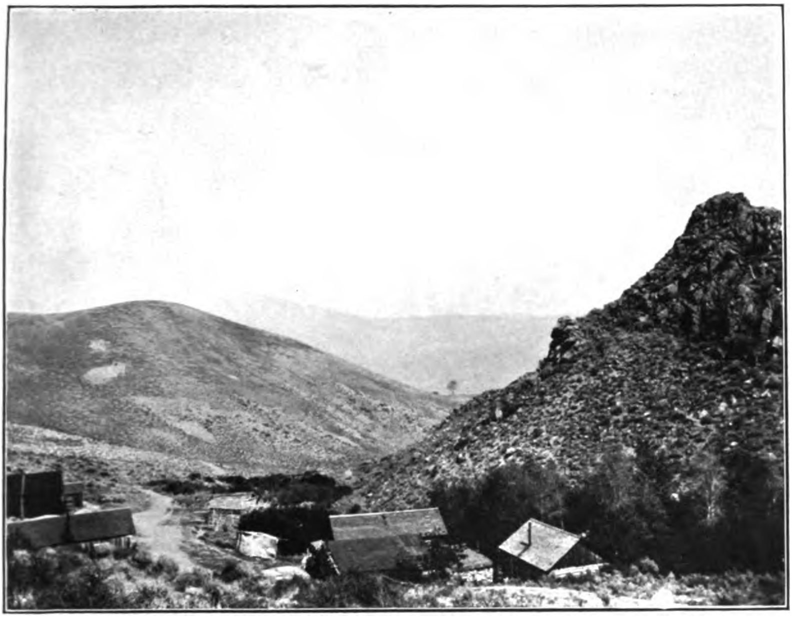
About 1880 copper ore was shipped from the Boston mine, on the north or Middle Stack contact, to Swansea, Wales, and to Boston.

During the decade that followed the country lay dormant until about 1887, when the Jules Verne and Midnight claims produced and shipped to Swansea, Wales, a carload of copper ore, and the Hanks property was located and bonded to an English syndicate by a German. In 1888 the present Delano group was located by Messrs. Hickey, Delano, Ayres, and Hechathin; in 1889 or 1890 the Brooklyn property by Messrs. Warwick, English, and two others; and about 1891 the Empire mine, which turned out well, by Mr. Dewith, and soon after the Copper Queen by Mr. Susettie, all being located for copper. It is also reported that about 1888 the Boston Copper Co. did about $20,000 worth of development work in the district, concerning which, however, nothing definite was learned. This was the extent of the camp until about 1895, when its activity was revived by the immigration of 60 or 70 men, making a total of more than 100 men working in various parts of the district. The present Ivy Wilson and Zetta Blanchard groups were located by W. T. McArdle, who in the following year mined and shipped from the Hanks



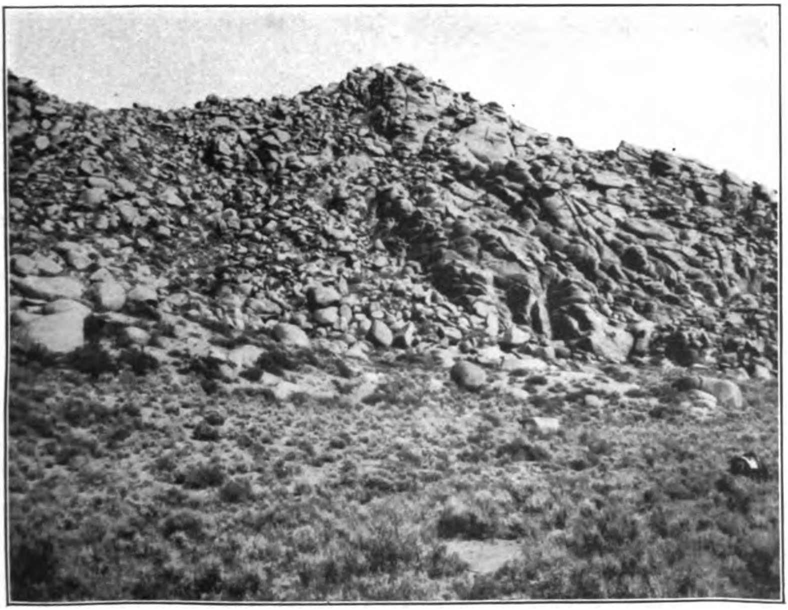
VIEW OF CONTACT (NEW TOWN).

Gently sloping intrabasin floor of eroded granodiorite in foreground, bounded by Ellen D. Range of outward-dipping Paleozoic sedimentary rocks forming rim of basin in background, with mines in face of range. Looking west-northwest.



A. VIEW OF OLD CONTACT.

In Town Gulch, with sheeted granodiorite butte on right and Delano openings in hill of Paleozoic sedimentary rocks on left. Looking N. 75° E.



B. CHARACTERISTIC SEDENTARY BOWLDERS PRODUCED BY WEATHERING OF THE GRANODIORITE IN THE CONTACT DISTRICT.

Looking southeast on Thompson Gulch and Bonanza road above White's camp.

property 8 carloads of ore that assayed 24 per cent of copper and 14 ounces of silver to the ton. In 1896 Mr. Bourne, of Wells, father of the well-known Jarbidge Bourne, located the Mammoth and adjoining claims on the east, and almost simultaneously the present Bonanza property, under the name Dolly B., was located by Messrs. Coleman, Moore, and Thompson, of whom the first named located the Father de Smet property of Hearst fame in the Black Hills. In the same year the Lucky Boy group, later known as the Emerald and now also as the Winnemucca group, was located by Mr. Armstrong. In 1896–97, with local aid in which 20 men contributed $100 each, a 50-ton smelter of the water-jacket type was installed about a mile south of the present new town, near the river, by the Salmon River Mining Co., of which S. P. Kemper, of Butte, Mont., was president, but the plant did not prove a success, and after a trial of three different runs, starting April 1, and a production of 14 tons of 98 per cent copper, from ore obtained principally from the Bluebird mine, was closed and has remained so to the present.

Soon after the trial of the smelter Mr. Kemper formed a company of the prospectors and miners in camp, with the view of mining the Brooklyn, Empire, and other properties and making a success of the smelter, but as the project was not successful and the members of the company could not keep up their assessments, Mr. Kemper, it is said, became sole owner of both mines and smelter. After failing to acquire also the Delano group, he closed the Brooklyn mine, which at that time was making one of the best showings in the camp. After this suspension of operations the population by 1898 fell to but 20 or 25 men, and the district slumbered until 1905, when, with only five men in camp and no companies working, there began a gradual revival of activity. By 1908 there were about 300 people in the camp, owing chiefly to the starting of operations on the Ivy Wilson group by the United States Mining Co. and on the Bonanza group by its owner. At present the camp has a population of about 100 people.

The principal settlement is the new town of Contact, of about two years' growth (Pl. XVII), favorably situated on a gentle slope about half a mile west of and 200 feet above the river. The place known as Old Contact or Old Town (Pl. XVIII, *A*) is now nearly deserted.

Railroad facilities seem likely to be soon supplied by the extension of the Oregon Short Line branch now in operation from Twin Falls to Rogerson, Idaho. The line has been surveyed southward up the Salmon River valley to Valley Pass, Nev., a point on the Southern Pacific Railroad between Cobre and Wells. The route is said to be feasible, and when completed the line will pass directly through the Contact district. At present, owing to the occupancy of the valley flats, under range fence, by the Vineyard Land & Stock Co., to the exclusion of small ranches, all supplies and ordinary ranch produce have to be freighted by wagon from the railroads.

The Twin Falls Power Co. has a branch plant at the Salmon River dam 30 miles north of Contact, and offers to supply the camp with power at reasonable rates. The Contact Power & Milling Co. contemplates the development of home power by the installation of a dam and plant on the river in the box canyon of the lava area a few miles west of Ellen D. Mountain.

GEOLOGY.

Like much of the Great Basin on the south, the Shoshone or Snake River basin on the north, and the Jarbidge district on the west, the Contact district lies in an area of folded and tilted sedimentary rocks, mostly Paleozoic, cut by granular intrusives and flooded by Tertiary lavas. (See Pl. XIV, p. 100.)

The rock groups of the district, beginning with the oldest, are Paleozoic sedimentary rocks, post-Paleozoic granitic intrusive rocks, Tertiary lavas, Tertiary lake beds, and Quaternary deposits. Of these the most important, with reference to the mineral deposits, are the post-Paleozoic granitic intrusive rocks and the Paleozoic sediments. Except that the old rhyolite of the Jarbidge district is absent and that lake beds are present, the geologic section at Contact is similar to that of the Jarbidge district.

SEDIMENTARY ROCKS.

PALEOZOIC ROCKS.

The Paleozoic sedimentary rocks which formerly covered the entire district now form merely an outward quaquaversally dipping belt encircling the granitic basin, as shown on Plate XIV. The belt ranges from a mile to several miles in width, the sedimentary rocks being in part underlain and intruded by the granitic rocks on the inner side and overlain by the Tertiary lavas on the outer side.

The rocks as exposed do not appear to be over 1,600 feet thick, as shown in the sections of Ellen D. Mountain and on the Ivy Wilson ground on the west. It is possible, however, that further field work may show a greater thickness between Old Contact and the northern edge of the area mapped.

The rocks exposed, however, do not necessarily constitute the entire section of the Paleozoic in this district, for if the granitic mass, as has been suggested by Purington[1] and Bailey,[2] represents a laccolith, the basal part of the sedimentary section must be deeply buried under the granitic intrusive. From the areal extent of the granodiorite, which occupies a belt 25 miles or more in length and 6 miles in width, and from its exposure through a vertical range of more than 3,000 feet without revealing any trace of sedimentary beds, it appears probable that the granodiorite may be a stock or batholith. The absence from the surrounding region of any section of the Paleozoic rocks of much greater thickness than that exposed in the district is also unfavorable to the laccolithic view. At Elk Mountain, 12 miles to the northwest (see Pl. I, p. 10), the Paleozoic section is about the same as in the Contact district. Further light will probably be shed on this subject when study is made of the H. D. Range, to the east, where the Paleozoic rocks appear to be displayed on a grander scale, with perhaps a much thicker section.

---

[1] Purington, C. W., Proc. Colorado Sci. Soc., vol. 7, 1903, p. 130; also Eng. and Min. Jour., vol. 76, 1903, p. 426.

[2] Bailey, J. T., Eng. and Min. Jour., vol. 76, 1903, p. 612.

In Ellen D. Mountain the rocks dip north at angles near 20° or lie nearly horizontal. On the Ivy Wilson and Bryan claims they are mostly on edge or highly tilted. Elsewhere they are variously deformed, distorted, folded, faulted, and brecciated. Some apparently detached portions of the strata, with steep inward dip, appear to be inclosed in the granitic mass, as indicated in the left part of section B–B′, on Plate XIV.

In some places the contact is therefore compound and comprises a zone several hundred feet wide in which bands of limestone or other sedimentary beds alternate with bands of granodiorite. This is particularly true of much of the contact on the northwest, extending from a point near the river 6 miles westward to Bonanza Gulch.

The contact, like some of the sedimentary beds, in places also dips inward toward the granodiorite, but wherever it has been followed for a few hundred feet in depth it straightens or assumes the normal outward dip, as at the Brooklyn mine.

No detailed examination of the Paleozoic rocks could be made in the time allotted to this work. So far as observed the exposed portion of the section consists principally of alternating beds of blue and white limestones, quartzites, and slate or dark slaty and shaly quartzite. In descending order the members are essentially as follows:

Section of Paleozoic rocks in Contact district.[1]

	Feet.
Granodiorite.	
8. Limestone	1,100
7. White limestone	
6. Bluish limestone	
5. Heavy quartzite	
4. Black limestone	
3. Reddish limestone shale	
2. Slate or dark slaty to shaly quartzite	300
1. Quartzite, basal (?)	200

---

[1] Nos. 3 to 8 principally from information supplied by J. V. Marshall.

The basal quartzite, as shown on the Bryan ground, has a thickness of about 200 feet and, as shown both here and on Strawberry Hill, on the Ivy Wilson ground, is a thick-bedded hard pinkish-gray rock, which weathers reddish brown.

The limestone varies from thin to thick bedded and, where in contact with the intrusive granodiorite, is usually silicified, garnetized, and in places chloritic or almost completely changed to diopside, with which are associated scapolite, calcite, and other metamorphic minerals.

In some places, however, the limestone near the granodiorite is but slightly altered; elsewhere it is highly metamorphosed for a distance of 1,600 feet or more from the contact. Most of the indications of ore occur in the altered and replaced limestone. The sedimentary rocks are cut also by dikes of syenite, monzonite, aplite, and rhyolite or felsite. (See pp. 109–112.)

No fossil remains were found in these Paleozoic rocks, but from their lithologic character and general resemblance to the nearest Paleozoic rocks of ascertained age,[1] which occur 10 miles south of the district, the rocks appear to belong to the upper Carboniferous portion of the Eureka region section.

TERTIARY LAKE BEDS.

In the valleys of the district, as well exposed in its southeastern part on Knoll Creek (Pl. XVI, *B*), occur water-laid deposits of whitish to dull-gray sandstone. This formation rests unconformably upon the eroded surface of the Paleozoic sediments, the granodiorite, and the Tertiary volcanic rocks and in large part underlies the late Quaternary deposits on Salmon River, in the large, gently sloping quadrangular embayment between Meadow Creek and Middle Stack Mountain (Pl. XIV, p. 100) and seemingly also between Meadow Creek and McDuffy Gulch. In the undulating hilly country north of Middle Stack Mountain the formation occupies the widening valley of Trout Creek and, as on Knoll Creek, it appears to extend almost to the headwaters of the stream, reaching an elevation of about 6,600 feet.

The thickness of the formation, which depends on the underlying topography and on the extent of later erosion, varies in places from less than a foot to a known maximum of about 400 feet on Knoll Creek, although it may locally be much greater.

The formation for the most part lies nearly horizontal but in places is tilted, flexed, and gently folded. It tends to weather in bluffs and miniature badland forms, as shown in Plate XVI, *B*.

The beds are of various thicknesses and the layers are not sharply defined. They are composed of light, friable, almost pumiceous volcanic tuff deposited as ash showers in a Tertiary lake. Under the microscope the tuff is seen to consist of minute elongated particles of glass which along their edges show feeble polarization. There are also present a little biotite and hornblende.

---

[1] U. S. Geol. Expl. 40th Par., Atlas, Map IV.

It is possible that some deposits of coarser angular volcanic tuff, 100 feet or more thick, that occur in the vicinity of Contact and elsewhere, may represent shore or delta deposits associated with the finer lake beds, but such connection was not investigated in this work.

At Contact tuffaceous sandstone of medium grain is penetrated by a 72-foot well, with its bottom still in this rock, and at Lower Town a 90-foot well is almost wholly in this light tuffaceous sandstone, with some argillaceous material, although its bottom is in granodiorite, 60 feet below the level of the river. Water was finally obtained here by drilling laterally on a moist seam 20 feet above the bottom of the well.

No fossil remains were found in the lake beds, but from their lithologic character and their relation to the other rocks of the district they appear to be of Pliocene age and to belong to the Humboldt formation, which occurs extensively in northern Nevada, as described on pages 31–32. According to the Fortieth Parallel Survey,[1] it covers large areas in northern Nevada, and it is known to extend within 8 or 10 miles of the Contact district on the south.

IGNEOUS ROCKS.

The igneous rocks of the district comprise several types of granitic intrusive and Tertiary volcanic rocks. Of these the oldest and most important are the intrusives.

INTRUSIVE GRANITIC ROCKS (CRETACEOUS?).

The oldest of the granitic rocks is the granodiorite. Economically it is also the most important, for the discoveries, prospects, and developments are mainly near the contact between the granodiorite and the Paleozoic sedimentary rocks, especially limestone. The granodiorite area has a width from north to south of 6 miles and a length of over 25 miles. Its outline, defined by the surrounding Paleozoic sedimentary rocks, is well marked by Ellen D., Middle Stack, China, and other prominent mountains. At nearly all these places the granodiorite is plainly intrusive into the sediments, which it has uplifted with quaquaversal outward dip along the contact. From this and other phenomena observed at Ellen D. Mountain, on the west, it is evident that the Paleozoic sedimentary rocks formerly extended entirely over the granodiorite as a huge elongated anticlinal dome, practically coextensive in area with the present basin.

---

[1] U. S. Geol. Expl. 40th Par., Atlas, Map IV.

The granodiorite therefore intrudes and in part underlies the surrounding sedimentary rocks. It is locally overlain by Tertiary volcanic rocks, Tertiary lake beds, and Quaternary alluvium, and is cut by syenite, monzonite, aplite, and felsite dikes. It is much younger than the Paleozoic sediments, and like the granodiorite of the Jarbidge district, which it resembles, is probably of Cretaceous or near Cretaceous age.

Since its intrusion the granodiorite has suffered considerable disturbance. It is faulted, fissured, and generally sheeted. Locally, as at Ellen D. Mountain and in the Johnson tunnel on Trout Creek, it is sheared and laminated. For instance, in the western part of the basin, on Thompson Gulch, about midway between the Bonanza, Brooklyn, and Ivy Wilson mines, it is cut by a pronounced dominant N. 70° E. sheeting with a dip of 80° S. and by a second sheeting that dips steeply to the west. Owing to these structures the rock weathers concentrically into huge heaps of sedentary bowlders, as shown in Plate XVIII, *B* (p. 102). Examples of shearing and lamination occur about a mile east of Old Contact, on the Palo Alto and Bryan ground.

The granodiorite, as well shown at the Brooklyn mine and elsewhere, is a gray, coarsely speckled rock, of medium to moderately coarse grain. It contains feldspars two-tenths of an inch in maximum diameter, quartz in moderate amount only, biotite, and hornblende crystals one-tenth of an inch in maximum length. Under the microscope the rock is seen to have a eugranitic, hypidiomorphic granular texture and to be composed essentially of plagioclase, orthoclase (including microcline), quartz, pale-brown biotite, and hornblende. The feldspars show zonal structure. Some are kaolinized or altered. The hornblende is partially altered to chlorite and has associated with it considerable magnetite. In certain specimens the minerals are bent by dynamic action. The plagioclase is principally oligoclase and stands close to oligoclase-andesine.

TERTIARY VOLCANIC ROCKS.

The Tertiary volcanic rocks occur as flows, with local beds of associated ash or tuff and allied volcanic ejecta, resting unconformably upon the Paleozoic sediments and extending outward in all directions over the surrounding plateau. They also occur as local inliers within the granodiorite area, where they form bluffs along the streams, as on Meadow Creek and Salmon River at Lower Contact, or cap flat-topped buttes, of which Table Mountain, near Old Contact, the similar butte near San Jacinto, and others on Trout Creek near Clark Cabin are conspicuous examples. The presence and general accordance in elevation of these inliers indicate that these lava flows formerly extended continuously over the entire region.

The lavas nowhere appear to attain a great thickness. Their thickest section is probably at Ellen D. Mountain, where, according to Purington,[1] they have a thickness of about 500 feet. The lavas occur in thin to moderately thick flows superimposed one upon another and in places showing fine fluxion laminations, from which it may be inferred that in the molten state they were very fluid. They are mostly dense or aphanitic rocks. On fresh surfaces they are bluish gray, and they weather brown.

These lavas, like the young or rim-rock lavas of the Jarbidge district, have hitherto been commonly known as basalt. Examination, however, shows them to be rhyolite very similar to or identical with the rim-rock rhyolite of the Jarbidge district, with which, to judge from a rapid traverse made between the districts, they appear to be practically continuous. Like the rhyolites at Jarbidge, they consist essentially of a glassy felsitic groundmass and contain considerable tridymite. In fact, so closely does the description of the rhyolites of the Jarbidge district apply to these lavas that it would be superfluous to repeat it here. (See pp. 42–47.) To judge from the overlying eroded sediments and associated deposits, the rhyolites of the Contact district probably contain more ejecta than those at Jarbidge.

DIKE ROCKS.

CLASSES AND GENERAL FEATURES.

The dike rocks observed in the Contact district may be roughly grouped into two main classes—(1) syenitic or siliceous and (2) lamprophyric or basic. Both are younger than the granodiorite, which they cut, as they do also the Paleozoic sedimentary rocks. The basic dikes, according to W. T. McArdle[2] and J. T. Bailey,[3] are younger than the siliceous dikes. As seen on the Bryan ground and elsewhere the basic dikes weather down evenly with the inclosing rocks, but the siliceous dikes outcrop in places 10 feet or more above the surface.

According to Lindgren[4]—

> It is well known that large intrusive areas usually contain a series of dikes filled with molten magmas shortly after the consolidation of the main mass. The composition of these dike rocks is very apt to bear a certain relation to that of the main intrusive mass, and it is held by some that the dikes represent products of differentiation derived from the principal magma. In case of certain rocks like nepheline syenite, the dike rocks are especially characteristic.

---

[1] Purington, C. W., The Contact, Nevada, quaquaversal: Proc. Colorado Sci. Soc., vol. 7, 1903, p. 131.

[2] Oral communication.

[3] Eng. and Min. Jour., vol. 76, 1903, p. 612, map.

[4] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 85.

This statement is characteristically true of the Contact district, in which the principal dikes are syenite and syenitic rocks composed essentially of orthoclase feldspar, one of the principal mineral constituents of the granodiorite. The dikes include also, however, monzonitic and aplitic rocks.

SYENITIC OR SILICEOUS DIKES.

The syenitic dikes are widely distributed and cut both the granodiorite and the Paleozoic sedimentary rocks. They are more plentiful or at least are more conspicuous and have been more frequently observed in the granodiorite, in which they are usually associated with ore deposits. The more feldspathic varieties weather evenly with the country rocks (Pl. XXIII, *A*, p. 118). They strike as a rule a little north of east. They are mostly from 1 to 3 or 4 feet in width, but locally they attain a width of 200 feet or more as shown on the Salt Lake ground near Contact and on the Camp Bird claim, 2 miles east of the river.

The rock is generally pale pink or flesh-colored, especially in the weathered state, but some varieties are light to iron-gray. It is granitic in texture and somewhat closer grained than the granodiorite. In the weathered state it appears somewhat porphyritic, with tabular feldspar phenocrysts, whence it is commonly known as porphyry. It is moderately miarolitic, with small cavities some of which contain chalcedonic or hyaline silica. The dikes represented on the map (Pl. XIV, p. 100) are nearly all of this class, particularly in the granodiorite area. They are of economic significance from the fact that they are usually associated with ore or indications of ore, especially in the granodiorite area; the Shield, Pool, and Camp Bird dikes described later are examples.

The rock is predominantly feldspathic and is composed essentially of orthoclase, with usually a smaller quantity of plagioclase, albite, etc., very little hornblende or other bisilicates, and, in its typical form, little or no quartz. Apatite, octahedrite, magnetite, and rutile are present as accessories. A specimen (No. 84) from White Elephant No. 3 of the Ivy Wilson ground shows the accessory octahedrite or titanium dioxide, TiO_2, very plentifully present in pleochroic, strongly double-refracting striated octahedra and modified forms.

From true syenite the rock in different localities or dikes ranges to monzonitic and to siliceous or aplitic varieties. For instance, a specimen from the Pool dike, which cuts the granodiorite near Contact, shows this dike to be composed of orthoclase (perthitic) and plagioclase in about equal proportion, a very little quartz, and a moderate amount of bisilicate, now represented chiefly by pale-green chlorite. The plagioclase corresponds mostly to oligoclase-andesine and the rock seems to stand close to monzonite. It contains considerable sericite, some being in rosettes.

Near Clark Cabin, on Trout Creek, the granodiorite is intruded by numerous dikes and by a small stock of a light flesh-colored fine-grained rock composed of orthoclase, plagioclase, and quartz in about equal proportions, with a little disseminated hornblende and a very little biotite. It appears to stand between quartz syenite and quartz monzonite.

On the Camp Bird ground, at the head of McDuffy Gulch, the granodiorite is cut by a persistent 200-foot dike of a similar but coarser-grained porphyritic rock composed of about 40 per cent each of orthoclase and plagioclase, both considerably sericitized, about 20 per cent of quartz, and but a small amount of bisilicate. This rock is apparently a quartz monzonite.

At the Chinaman mine, in China Mountain, the limestone and the granodiorite, which is here comparatively basic, are cut by a fine-grained dike that is macroscopically similar to that near Clark Cabin, but is composed principally of orthoclase and quartz, with a very little plagioclase and apatite, and stands close to aplite.

LAMPROPHYRIC OR BASIC DIKES.

The lamprophyric or basic dikes appear to be less plentiful and smaller than the syenite dikes. They were observed chiefly in the western and northern parts of the district, where they are intrusive into both the granodiorite and the sedimentary Paleozoic rocks and are said to cut the syenite dikes also. They trend for the most part north-northwestward nearly at right angles to the general trend of the syenite dikes. They were observed at several points. On the Bryan ground, near Contact, in the gulch to the southeast of the shaft, a dike nearly 8 feet wide cuts the quartzite. In the southeast base of Ellen D. Mountain a dike of this class is intruded into both the granodiorite and the Paleozoic sedimentary rocks; and at the top of the mountain, according to a specimen collected by Sweetser, the sedimentary series is cut by a similar dike, possibly the same one.

The dikes of this class are dark. They range from iron-gray to nearly black and are moderately porphyritic, with small phenocrysts of pinkish feldspars and dark-brown hornblende in an aphanitic or microcrystalline groundmass of plagioclase, hornblende, biotite, and usually a moderate amount of quartz, although the dike in the top of Ellen D. Mountain shows little if any quartz. The groundmass is holocrystalline, is nearly equigranular, and shows fluxion structure. The plagioclase ranges from oligoclase-andesine to andesine-labradorite. The hornblende is in long prisms and much of it is changed to chlorite and epidote. The rock of these dikes is essentially a hornblende basalt and stands close to camptonite.

These dikes are locally called porphyry or bird's-eye porphyry and seem to be the dikes described by Purington[1] as felsite and by Bailey[2] as felsitic dikes.

SUMMARY OF GEOLOGIC HISTORY.

During Paleozoic time in the area now corresponding to the Contact district sediments were deposited on the floor of the ocean as mud, silt, carbonate of lime, sand, etc. Later these deposits were elevated above the sea as shales, limestones, and quartzites, their elevation presumably being accompanied by deformation, folding, and faulting. Of early Mesozoic changes, which, as indicated in neighboring regions, were probably extensive, no records remain in the district. Apparently, near the end of the Cretaceous period, the granodiorite batholith was intruded into the Paleozoic rocks, the intrusion being accompanied by an anticlinal uplift, particularly through the east-west central belt of the district, and by folding, faulting, and other deformation. A little later the rocks were intruded by the syenitic and lamprophyric dikes, which traverse both the granodiorite and the Paleozoic sediments. The ore deposition appears to have been associated with the intrusion of the granodiorite and these dikes and was probably effected by thermal solutions and gases that followed the intrusion.

The intrusion of the granodiorite batholith, which probably fractured the overlying Paleozoic rocks, was followed by a long period of erosion in which the entire arch of the anticline was removed ard its limbs truncated to the form of the rim of the granodiorite basin.

In Tertiary time an outpouring of rhyolitic lavas flooded the entire district and during the later part of this volcanic epoch the low places of the district were occupied by lakes in which, among other sediments, beds of tuffaceous sandstone, etc., constituting the Humboldt formation (Pliocene), were deposited. These beds have since been largely removed by erosion, which has continued to the present time and which, in connection with local transportation of material, in places has buried what remains of the lake beds under Quaternary débris derived from the surrounding slopes and mountains.

MINERAL DEPOSITS.

LOCATION AND GENERAL CHARACTER.

The mineral deposits of the Contact district occur principally in the contact zone of the granodiorite and within the granodiorite area in connection with the dikes. They lie on a curve nearly 50 miles

---

[1] Purington, C. W., Eng. and Min. Jour., vol. 76, 1903, p. 427.

[2] Bailey, J. T., idem, p. 612.

N PART OF THE C

long, which from its shape is locally called "the horseshoe." Most of them, however, are in the toe of the shoe, on the west or town side of the river. (See Pl. XIV, p. 100.) Their general distribution is shown in Plates XIX to XXII.

In the contact zone the deposits occur principally in the limestone at or near the contact. They appear to owe their origin to the intrusion of the deep-seated granular rocks, especially to the pneumatolytic gases and thermal solutions that accompanied and followed the intrusion. They are therefore probably of Cretaceous age.

The region is not characterized by a great variety of minerals. The following list gives those that have been observed:

Actinolite.
Allanite.
Apatite.
Aragonite.
Argentite.
Asbestos (?).
Augite.
Axinite.
Azurite.
Biotite.
Bornite.
Calcite.
Cerusite.
Chalcedony.
Chalcocite.
Chalcopyrite.
Chloropal.
Chrysocolla.
Cuprite.
Diopside.
Epidote.
Galena.
Garnet.
Gold.
Hematite.
Hornblende.
Hyalite.
Ilvaite.
Kaolin.
Limonite.
Malachite.
Microcline.
Molybdenite.
Muscovite.
Octahedrite.
Orthoclase.
Plagioclase.
Pyrite.
Pyrolusite.
Quartz.
Quartz (secondary).
Rutile (?).
Scapolite.
Sericite.
Specularite.
Spinel (?).
Titanite.
Tourmaline.
Vesuvianite.

The ores of the district are almost wholly copper ores, but they contain also small amounts of silver and gold. Some of the ore—for instance, that at the Bryan mine—is said to contain as high as 8 ounces of silver and from $10 to $12 in gold to the ton. The Blue Bird ore carries 20 ounces in silver and $2 in gold. In only a few places do lead, manganese, and zinc ores occur.

The ore minerals are malachite, argentite, azurite, chalcopyrite, bornite, chrysocolla, chalcocite, cuprite, galena, gold, cerusite, hematite, and pyrolusite. Of the copper minerals probably chalcopyrite alone is primary, the others being derived from it.

According to their mode of occurrence, the deposits may be roughly grouped into three classes—contact-metamorphic deposits, fissure veins, and replacement deposits. It is obvious that some deposits can not be assigned to any single class. In some openings deposits of two or more of the classes may be present and so intermingled or blended as not to be easily separated. A brief description, with examples of the different classes, follows.

CONTACT-METAMORPHIC DEPOSITS.

The contact-metamorphic deposits, as shown at the Queen of the Hills, Mammoth, Johnson, Zetta Blanchard, and other openings, consist essentially of a mixture of carbonates, massive garnet, axinite, epidote, calcite, quartz, actinolite, diopside, malachite, azurite, pyrite, chalcopyrite, bornite, copper oxides, specularite, hematite, limonite, chloropal, molybdenite, muscovite, etc. The minerals are all more or less intergrown and, except the oxides, were apparently all formed at the same time, probably by the contact metamorphism of the limestone by the intrusive granodiorite. The metals are copper and silver, with a little gold. The deposits occur on or near the contact of the two rocks, usually in the limestone, where they form irregular bodies 40 feet or more in width.

Garnet is generally present as a gangue mineral, but it is not so plentiful as at first appears. Much of the massive grayish-brown gangue mineral throughout the district that has hitherto been taken for garnet, even by the trained eye, is found on examination to be axinite. The garnet is almost wholly massive. Its occurrence in crystalline form is extremely rare; about the only example observed is in the Zetta Blanchard No. 5 shaft, where a few fairly well-formed, very impure crystals half an inch in maximum diameter were seen in a dark-brown or blackish ferruginous gangue. Portions of smaller crystals were noted in the axinite-chloropal gangue of the same opening.

An unusual and interesting feature of the deposits is the occurrence of axinite, a rather rare boron-bearing grayish-brown hydrous silicate of aluminum and calcium with iron and manganese. It is generally present as a gangue mineral throughout the contact zone. It shows plentifully in microscopic slides of the Brooklyn, Alice, and Zetta Blanchard ores, and specimens from a dozen or more different localities, covering all parts of the contact zone, examined chemically by W. T. Schaller, gave strong tests for boron, denoting the presence of axinite in considerable amount. It forms about 50 per cent of a thin section from the yellowish gray-brown gangue portion of the deposits in the Alice shaft and about 80 per cent of ore from the Zetta Blanchard No. 5 shaft.

The distinctive features of axinite are the presence of boron, which colors the flame green, its acute-edged crystal form, the combination of high refractive indices with low double refraction, and its good cleavage. In a thin section of ore from the Brooklyn mine the refraction of the axinite was found by J. B. Umpleby and Waldemar Lindgren to be higher than 1.650 and lower than 1.700, which agrees closely with published data.

Axinite is known to occur here and there on the borders of intrusive granitic and diabase areas, and has been noted by Ransome in the contact zone at Coppereid, Nev.[1] Hoerner[2] regards axinite as essentially a pneumatolytic mineral produced by the gases of a granitic magma in contact with a highly calcareous rock. If this view is correct it would seem that there must have been considerable pneumatolytic action in the Contact district, and probably the copper with the other ore constituents was introduced at the time of the intrusion.

Chloropal, plentiful in places as a gangue mineral, is a yellowish-green or finch-green hydrous silicate of iron and aluminum. It is not an ore of copper, and whatever copper it may contain has probably been mechanically introduced.

A typical specimen of the ore from the Alice shaft in places suggests crude banding, but as a whole is nearly massive. It is medium grained and consists principally of a mixture of malachite and azurite with a little chalcopyrite and bornite in a dark iron-stained garnetiferous axinite-quartz gangue. These constituents are intergrown with leaf-like veinlets of molybdenite, which form a sort of mesh. The latter feature is still better shown under the microscope, which also discloses the presence of much microcrystalline chalcedonic quartz, pyroxene, mostly altered to epidote and chlorite, and veinlets of epidote.

The contact-metamorphic deposits were the first to be formed, and their highly-colored outcrops, stained with copper carbonates, tend to convey a strong impression of the mineralization of the district. They are seemingly best developed around Ellen D. Mountain and China Mountain, but good showings also occur in the Middle Stack Mountain, Trout Creek, and Zetta Blanchard areas.

FISSURE-VEIN DEPOSITS.

Though less conspicuous than the contact-metamorphic deposits the veins appear to be the more promising. They are more regular and persistent.

After the intrusion of the Paleozoic rocks by the granodiorite the rocks were fissured and were subsequently intruded by the dikes already described. In the fissures circulating thermal solutions, in some cases after the intrusion of the dikes, deposited quartz veins containing ore minerals. Some veins follow or parallel the main contact, others cut across it nearly at right angles, and others occur chiefly in the granodiorite, in association with the dikes.

The veins appear to be best displayed along the portion of the contact zone that extends from a point north of Contact westward to the Bonanza mine. Most of them are from 1 to 4 feet wide and outcrop boldly from 1 to 8 feet above the surface. They contain little or no gouge. Examples are the Antelope vein, about midway between the new and old towns, and the veins on the Delano No. 2 and Copper King No. 1 claims, just north of Old Contact, all for the most part in the granodiorite.

---

[1] Ransome, F. L., Notes on some mining districts in Humboldt County, Nev.: Bull. U. S. Geol. Survey No. 414, 1909, p. 64.

[2] Hoerner, Thomas, Über die Axinitvorkommnisse von Thum in Sachsen und die Bedingungen der Axinitbildung überhaupt: Zeitschr. Deutsch. geol. Gesell., vol. 62, pt. 1, 1910, pp. 17–20.

The filling is glassy quartz, with a little chalcedony, and it contains the usual copper-ore minerals chalcopyrite, bornite, malachite, azurite, chalcocite, cuprite, and chrysocolla, all of which were probably deposited originally as chalcopyrite. Silver and gold are also present in small amount, and there is in many places some associated molybdenite.[1]

It is probable that further work may show that some of the veins now within the dikes, instead of having been deposited within a single dike, were formed alongside of one dike, and that a later dike was then intruded between the vein and the granodiorite.

REPLACEMENT DEPOSITS.

In some localities veins normally but a foot or two in width widen by replacement of the country rock. This feature was pointed out by C. W. Purington [2] in describing a set of narrow veins at Ellen D. Mountain which cross the granodiorite contact and in the limestone contain ore bodies nearly 50 feet wide. Essentially the same feature occurs at Middle Stack Mountain, and in the Delano veins near Old Contact J. T. Bailey [3] observed the replacement of quartz by a siliceous hematite intimately associated with secondary chalcocite, cuprite, and chalcopyrite. Chrysocolla, azurite, and malachite are also present. The replacement is sporadic and is developed best near the impervious slate belt where the circulation was arrested.

Bailey [4] also describes a vein which is only 1½ feet wide on the Delano No. 2 claim, but which on the Alto claim, the circulation having been arrested or turned back by the impervious slate, has been enlarged by replacement of the granodiorite to a maximum width of 7 feet.

It is probable that some of the bodies now regarded as contact-metamorphic deposits may belong to the replacement class and are connected in origin with veins or dikes not yet observed. As noted by Purington, it is the under side of the limestone bed that is usually the most mineralized or replaced by ore. This is natural and is especially to be expected where the deposits are of pneumatolytic origin, as appears to be the case in the Contact district, the under side of the beds being the side most exposed to the action of the ascending mineral-bearing pneumatolytic gases.

---

[1] A more detailed description of the vein ore appears in the section on the Brooklyn mine (pp. 117–119).

[2] Eng. and Min. Jour., vol. 76, 1903, p. 427.

[3] Idem, p. 613.

[4] Idem, p. 612.

Further details on the deposits are given in the descriptions of the different mines and prospects that follow, but as exploitation thus far, with a few exceptions, has been only in the oxidized zone, which, especially in the granodiorite, seems to extend to about 200 feet in depth, most of the openings expose chiefly oxidized ores.

DETAILED DESCRIPTIONS OF MINES AND PROSPECTS.

ELLEN D. MOUNTAIN AREA.

The Ellen D. Mountain or western area comprises the western portion of the granodiorite batholith and the part of the contact zone lying west of the river. It is nearly an equilateral triangle, with each side about 5 miles in extent. Some of the more important properties in this area are the Brooklyn, Delano, Empire, Blue Bird, Antelope, Bonanza, Ivy Wilson, Florence, Copper Shield, Yellow Girl, and Hickey.

The principal feature of the geology, as shown on Plate XIV (p. 100), is the curved contact zone with its scarp of Paleozoic rocks overlooking the granodiorite. Along the north side of the area the Paleozoic rocks are tilted and irregularly disturbed, and on the west, as shown on the Ivy Wilson ground, they are steeply upturned or on edge, but in the higher part of Ellen D. Mountain they lie for the most part nearly horizontal or dip gently northwest.

The area contains deposits of all three classes and the most extensive and deepest developments of the district. The general distribution of the deposits is shown on the vein and claim maps, Plates XIX and XXII. They occur mainly in association with the contact zone and with dikes principally in the granodiorite.

BROOKLYN MINE.

Among the deeper openings is the Brooklyn mine, situated on the open, gently eastward sloping ridge of Ellen D. Mountain, about a mile west of Old Contact, at an elevation of about 6,300 feet. (See Pls. XIV, p. 100; XXIII, *B*.) The property was located in 1889 or 1890 for copper by Messrs. Warwick, English, and two other partners. It is owned by the Brooklyn Mining Co. It is developed principally by a 210-foot shaft, a 300-foot crosscut tunnel driven from the bottom of the shaft northeastward into the mountain, with a depth of 300 feet at the face, and a 300-foot "tunnel" or drift which starts to the northeast about 90 feet above the shaft and is driven N. 65° W. on the contact and vein. The principal equipment is a 15-horsepower gasolene hoist, which is housed. The shaft is well timbered, is in good condition, and was unwatered in 1909. The water level stands at about 90 feet below the surface. The mine could not be entered at the time of visit.

The production, which is not large, was not learned. Some ore was produced when the Contact smelter was in operation. The mine is on the so-called Brooklyn vein or main granodiorite and Paleozoic rock contact, which is here compound. The principal Paleozoic member at this point is the white limestone, but an inlier or detached band of blue limestone is also included in the granodiorite. The blue band, according to Bailey,[1] is metamorphosed, silicified, and chloritic, and where encountered in the 300-foot crosscut its junction with the granodiorite shows secondary quartz with bornite.

The shaft was sunk in the granodiorite, then supposed to be the hanging wall, at a point several hundred feet from the contact, with the expectation of striking the vein in depth, as at the surface the vein dips inward or south toward the granodiorite. The dip, however, seems to steepen rapidly below the surface, for, after sinking 210 feet and crosscutting 300 feet from the bottom of the shaft, the vein was encountered on the contact, with granodiorite forming the footwall and limestone the hanging wall. The mineralization or ore was mostly in the limestone and in the 25-foot winze in the bottom of the mine. At the end of the crosscut the vein, it is said, stands about vertical, has a width of about 8 feet, and contains a shoot or streak of rich bornite-chalcopyrite ore 10 to 25 inches wide, which is variously reported to range from 3½ to 25 per cent in copper, with moderate values in gold and silver. These reports are borne out by the ore seen on the dump, most of which would by estimate run about 15 per cent. There are said to be two veins, one on the granodiorite side of the contact and one on the limestone side.

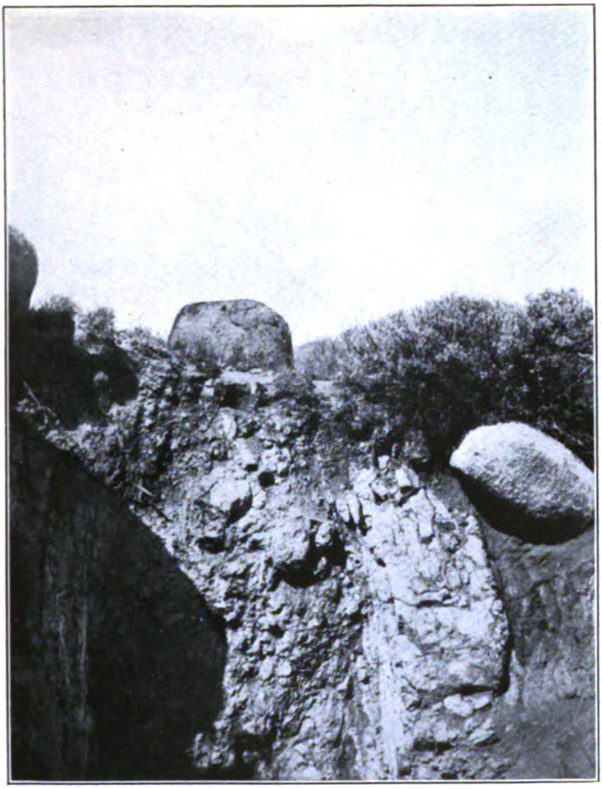
It seems very probable, also, from the amount of garnetiferous axinite-epidote gangue material on the dump, the width of the lode, and the reports of much ore in the limestone and of two veins—one on each side of the contact—that the deposits are contact-metamorphic as well as fissure-vein deposits.

The principal part of the ore as seen on the dump is a mixture of fine-grained or massive chalcopyrite and bornite with a nearly glassy vein quartz and is in part crudely streaked or banded. Honeycombed masses composed of skeletal casts show that the quartz has here and there replaced bunches of finely crystalline calcite.

A microscopic section shows most of the gangue to be characteristic vein quartz in which the chalcopyrite occurs irregularly or connectedly as filling, both massive and in cuboidal crystals and grains. The bornite occurs mainly as irregular inclusions or filling within and as veinlets traversing the chalcopyrite and seems to be secondary. With

---

[1] Bailey, J. T., The ore deposits of Contact, Nev.: Eng. and Min. Jour., vol. 76, 1903, p. 612.



A. ORE-BEARING SYENITE DIKE CUTTING COUNTRY-ROCK GRANODIORITE ON PORTLAND GROUND.

Looking west.

B. BROOKLYN MINE, LOOKING N. 65° E.

it occurs also considerable axinite and some impure massive garnet. Minute chalcedonic veinlets are sparingly present.

At the mouth of the tunnel the ledge shows a mineralized width of about 8 feet and contains carbonates and oxide of copper in sheeted granodiorite, apparently with associated syenite dikes. This mineralization, however, does not seem to continue more than 40 or 50 feet beyond the portal. Near the vein in the bottom of the mine thin seams and plates of native copper occur in the granodiorite.

ALLEN AND DELANO CLAIMS.

In its easterly extension from the Brooklyn ground the Brooklyn vein, or the contact representing it, traverses successively the Allen No. 2 and Delano No. 1 claims of the Delano group; thence, curving southeastward, it is regarded as the same vein on which the Bryan shaft is located, to the east of the Palo Alto ground.

In the Allen No. 2 claim a 40-foot crosscut tunnel shows the lode to have a mineralized width of about 100 feet and to consist of alternating bands of altered and mineralized granitic rock and thin layers of limestone, all capped with gossan, as on the Brooklyn claim. To the east of this tunnel a 10-foot shaft shows considerable 8 per cent carbonate of copper ore, with no wall yet reached.

On the Allen No. 2 and Delano No. 1 claims this lode is paralleled by a similar vein or lode which lies about 200 feet distant on the south, and on the Delano No. 1, where the country rock is chiefly whitish limestone, both lodes are opened by shafts 50 feet or more deep and make a fair showing of ore containing red and black oxides with carbonates. The ore is said to average about 50 per cent in copper and to be some of the best in the district.

EMPIRE MINE.

The Empire mine is about half a mile southwest of Old Contact, on open patented ground. It was located by Mr. Dewith in 1891 and is now owned by the Salmon River Mining Co. It is developed by a 360-foot shaft, reported to be the deepest opening in the district. The shaft is sunk in the granodiorite about one-fourth mile from the limestone contact, which occurs on the Brooklyn ground, on the north. It is on a "fissure vein" which dips steeply to the south, into the granodiorite, and is said to continue strong throughout the depth of the shaft. The mine was worked at the time the smelter was operated and contributed ore to it in 1886, but since then, after a breakdown of the pump and some caving in at the bottom of the shaft, the property has been idle.

To the northeast the vein seems to traverse the Arkansas and Western Union claims of the Delano group, and to the southwest the Empire extension and other ground.

PALO ALTO MINE.

The Palo Alto mine is about half a mile east of Old Contact and the same distance northwest of the new town, at an elevation of 5,900 feet, on the inner slope of the basin rim. (See Pls. XIV and XV, *A*, p. 100.) It was discovered in 1894 and 1895, and is now owned by the Nevada Copper Mining, Milling & Power Co.

It is developed by a 292-foot shaft, a 150-foot crosscut tunnel, 300 feet of drift, and 100 feet or more of crosscuts and stopes distributed on four levels, the whole being said to have cost more than $8,000. The 50-foot level contains the crosscut tunnel, 150 feet of drift, and 50 feet of crosscut; the 100-foot level, 30 feet of drift and 50 feet of crosscut; the 290-foot level, 125 feet of drift and 25 feet of crosscut; and the 250-foot level has 30 feet of stope.

The mine has produced about 300 tons of ore, most of which averaged about 32 per cent in copper, with $3 in gold and 8 ounces of silver to the ton. The ore was shipped to Selby and elsewhere, and considerable ore now lies on the dump.

The mine is in the contact zone, within a few hundred feet of the main granodiorite body. The contact here is more or less irregular and compound. The country rock is chiefly dark coarse Paleozoic slate with some associated pinkish quartzite. The crosscut tunnel starts in the quartzite, which is the same as that at the Bryan mine and is shown in the two outcrops proceeding from center to right about on a level with the lower dump in Plate XV, *A* (p. 100). The slate is blocky and seamed with calcite. The rocks are upturned and dip toward the contact or granodiorite at angles of about 75°. They are intruded by radial dikes, tongues, or sheets of granodiorite which seem to be offshoots from the main mass and which, following the nearly vertical bedding or cleavage planes of the slate, thin out as they recede from the main contact.

The deposits are contained in a small fissure vein in one of the 40-foot dikes or sheets of the granodiorite in the upper part of the mine and the shaft is sunk on the vein, which dips steeply to the south, about parallel with the sedimentary rocks and the dike. In depth, however, the dike seems to thin out, as does also the fissure, which ends at the lower contact of the dike with the impervious slate, with the result that the lower 200 feet of the shaft and other workings are in barren slate, approximately as shown in a diagram by Bailey.[1] The best prospect for ore on this property would seem to be to follow the vein westward into the granodiorite, away from which and from other dikes the slate seems to be barren.

This vein is thought to be the same vein as that on which the Blue Bird, Copper King No. 2, and other openings on the Delano group are located.

---

[1] Eng. and Min. Jour., vol. 76, 1903, p. 613.

BLUE BIRD MINE.

The Blue Bird mine is two-thirds of a mile northwest of Contact and about one-fourth mile northeast of the Palo Alto mine. It is on open ground, on the outer slope of the contact-zone ridge, at an elevation of about 5,800 feet. The property comprises a group of 12 claims and, like the Palo Alto, is owned by the Nevada Copper Mining, Milling & Power Co., of Contact, with headquarters in Tacoma, Wash.

This mine was discovered in 1884 and located by A. J. and Isaac Reed and William Southard. It is developed mainly by a southwesterly 70° incline with chambers and crosscuts.

The total production was not learned. From an ore heap, of which 300 tons of principally 8 to 10 per cent carbonate ore still lies on the dump, 100 tons of ore shipped to the Selby and Contact smelters is said to have averaged respectively 32 per cent and 17 per cent of copper and about 20 ounces of silver and $2 in gold to the ton.

The deposit is located about 1,200 feet out from the main contact, seemingly in a northeast-southwest fissure in whitish limestone, in which it seems largely to be a replacement; perhaps it is also in part a replacement of a dike. On the north the limestone is bounded by a band of quartzite which, toward the north side of the claim, is in turn succeeded by limestone.

The limestone at the mine is in part silicified or associated with quartzite. The deposit dips about 60° SE. toward the contact. The ore body in general has a width of 1 to 3 feet, but in places it exceeds the width of the shaft.

On the 60-foot level the ledge seems to be cut off by a cross fault or "watercourse," but crosscuts extended to the southeast may show ore. In the watercourse extensive deposition of quartz and calcite has silicified the adjoining limestone.

The ore contains principally malachite, red and black copper oxides, and some chalcocite or glance. A brown banded phase of it locally known as "copper silicate" is said to run high in copper values. The deposit seems to contain several thousand tons of ore that can be shipped as soon as railway facilities become available.

DELANO AND COPPER KING CLAIMS.

The Delano group, comprising eight claims and trending for three claim lengths in an east-west direction, centers a little northwest of Old Contact. It was mostly discovered and located late in the eighties by Messrs. Hickey, Delano, Ayers, and Hechatin, and since 1905 has been owned by the Seattle-Contact Copper Co., with headquarters at Seattle and Contact. The deposits on the north tier of claims have been described under the heading "Allen and Delano claims" (p. 119). Those on the middle tier, the Delano No. 2 and Copper King Nos. 1

and 2 claims, contain two veins regarded as the westerly extensions of the Palo Alto and Blue Bird veins. These veins, situated about 150 feet apart and nearly parallel, after traversing the Delano No. 2 and Copper King No. 1 in a westerly direction, seem to unite finally on Copper King No. 2, whence the deposits continue westward across the Bell claim as a single vein. This vein, taken in connection with the Palo Alto or southern of the two veins east of the junction, is said to be continuously and plainly traceable by the copper carbonate color of the quartz croppings for a distance of about 8,000 feet. On the Delano No. 2 ground, however, the veins seem to be materially interrupted or pinched by the impervious slate. On the Copper King claims they lie in the granodiorite and make a considerable showing.

The vein filling is the glassy quartz; and the mineralization, which is sporadic, as suggested by Bailey,[1] seems to be a replacement of the quartz by siliceous reddish-brown hematite intimately associated with the secondary copper minerals, chalcocite, copper oxides, chalcopyrite, and chrysocolla; the carbonates azurite and malachite are also present.

On Copper King No. 2 the Palo Alto vein dips about 70° S., is from about 1 to 3 feet in width, and contains considerable 5 per cent copper ore, with small values in gold and silver. The ore contains brown and black copper oxides, chrysocolla, and chalcocite or glance in kidneys and lenses, some ranging as high as 60 per cent in copper. Here the principal opening is a 200-foot crosscut tunnel, all in westward-dipping sheeted granodiorite intruded by parallel medium-grained pinkish syenitic dikes. The tunnel lacks but 40 feet to reach the Palo Alto vein, and at about 30 feet from the face it cuts a 14-inch blind quartz vein containing a little copper. The tunnel is in part old work, but it is in good shape.

On the east end of the Copper King No. 1, at an elevation of about 6,000 feet, at the upper " tunnel," the Palo Alto vein dips 60° S., and it is opened by a 200-foot drift run toward the west. Here the vein is about 6 feet wide, has a quartz gangue filling, and carries about 2 feet of copper ore which is best on the hanging-wall side.

At the lower tunnel, which is about 70 feet lower on the slope, the vein is opened by a 260-foot drift, in which the ore, said to be more than 3,000 tons, is left blocked out in the mine, except about 50 tons, which has fallen down. Here also the vein is about 6 feet wide and is confined by fairly good granodiorite walls which have locally almost 2 feet of kaolinized gouge on either side.

ANTELOPE MINE.

The Antelope mine is about one-third of a mile northwest of Contact, on open ground. It is on the Worth claim, formerly the

---

[1] Eng. and Min. Jour., vol. 76, 1903, p. 613.

Starlight. The property was discovered about 1898 and was recently sold by Ludnow Kroof to the present owner, the Antelope Mining Co., of Contact, said to be incorporated. It is developed by 200 feet of tunnel and about 100 feet of shaft, the deepest shaft being about 60 feet deep. The company is planning for continuous and more extensive developments.

The mine is now working on a small scale near the middle of the property, mainly through an 80-foot tunnel that opens on Town Gulch. In July, 1910, a carload of high-grade ore that averaged $101 to the ton was shipped from this mine to Salt Lake. A carload of ore was shipped some years ago from a 125-foot tunnel on the northeast end of the claim, with good returns.

The country rock is the granodiorite. The mine is about 600 feet from the nearest contact, at which the intruded rocks are the Paleozoic pulplish-pink quartzite and dark slate, the same as on the Bryan ground to the north. This mine is of special interest in being a type of the producing and promising deposits occurring in the granodiorite and seemingly not associated with the contact zone. The granodiorite is sheeted in a northeast-southwest direction about parallel with the vein.

The main workings are on the Antelope vein, which has also been called the Jules Verne vein. The vein dips south, away from the contact at angles of about 80°. Its outcrop or those of the silicified granodiorite, particularly on the south or hanging wall, rise in places 8 feet above the surface, or about 70 feet above the portal of the tunnel. It has a width of about 2 feet. The filling or gangue is glassy quartz in which, mostly in a pay streak or ore shoot from 6 inches to 2 feet in width, are contained the usual copper carbonates and red and black oxides. Besides the copper the ore contains about 6 ounces of silver to the ton and some gold. The bottom of the shaft seems to be entering the sulphide zone.

To the northeast, on the London claim, the Antelope vein is opened by a 30-foot shaft with a reported fair showing, and on the southwest it traverses the Jules Verne ground, where in 1887, together with the Midnight claim, it produced and shipped to Swansea, Wales, a carload of copper ore.

About 75 feet north of the Antelope vein and paralleling it in strike, but with about vertical dip, is a similar vein, from 1 foot to several feet in width, which, where opened by a shaft on the Antelope ground, is said to yield assays of 47 per cent of copper, with 6 ounces of silver and $11.60 in gold to the ton.

QUEEN OF THE HILLS PROSPECT.

The Queen of the Hills prospect is about a mile west of Old Contact and about half a mile west of the Brooklyn mine, on open ground in a low hill at an elevation of 6,500 feet. It is owned by the Nevada Copper Mining, Milling & Power Co. and is located on the westward extension of the same main contact between granodiorite and white silicified limestone or quartzite as the Brooklyn mine. The prospect is opened by a 60-foot drift extending eastward on the contact in the upper slope of the hill, and a winze 20 feet in length sunk to a depth of 6 feet below the floor of the drift. Including an open cut to the right or south, the openings show the deposit to have a width of at least 10 feet. It consists mostly of reddish, brownish, and greenish stained gossan-like garnetiferous calcitic gangue, containing considerable iron and copper oxides, malachite, chalcopyrite, bornite, etc., and seems to be of the contact-metamorphic type. By reason of the coloration, the opening presents an impressive showing.

RATTLER PROSPECT.

About 200 feet north of the Queen of the Hills opening is a lode or mineralized belt 120 feet wide known as the Rattler " vein," which seems to be an easterly spur or offshoot from the main contact. It follows approximately the strike of the limestone in which it occurs and which the contact traverses obliquely. The limestone, which here consists of heavy-bedded white and thin-layered blue rock, stands about vertical or dips steeply to the south-southeast, toward the granodiorite. The lode is exposed in a gulch which cuts across it. It is similarly exposed in a gulch about one-eighth of a mile to the west, but in the intervening ridge it disappears beneath the limestone, in whose beds at greater depth its mineralization occurs. Its exposure in the gulches therefore seems to mark approximately the upward limit to which the contact mineralization due to the granodiorite penetrated in the limestone at this place. The extent of this mineralization above the granodiorite will probably be disclosed in future underground work.

Toward its west end, at about 100 feet in from the contact, the Rattler property is opened by a 40-foot cut and winze, and shows considerable copper carbonate and oxide in garnetized granodiorite with associated syenitic dikes.

MAMMOTH AND NEIGHBORING PROSPECTS.

From the Queen of the Hills and the Rattler prospects the mineralization continues interruptedly westward along the contact in the south slope of Ellen D. Mountain for a distance of about 2½ miles to the Bonanza mine. The zone varies from 100 to several hundred feet in width and contains two or more contacts; in other words, the contact in places is compound, with outlying or detached vertical bands of limestone contained in the granodiorite and with here and there associated parallel and transverse dikes and veins. The ground is mostly owned by the Nevada Mining, Milling & Power Co. and is in the prospect stage.

Among the openings on the east are the Alice and Magnolia. On the Alice ground, which is opened by a shaft, the lode for about 400 feet parallels the Rattler lode on the north and dips 75° S. toward the granodiorite. The ore, which is said to average well in copper and silver, contains some molybdenite and epidote and occurs mostly in streaks or bands in a siliceous gangue of axinite, epidote, hematite, and garnet, of which axinite and the brown acicular epidote seem to constitute about 50 per cent, garnet being only sparingly present.

Farther west, on the Magnolia ground, which contains two parallel lodes at the contact of granodiorite and white limestone, separated by 150 feet of granodiorite and dipping steeply to the south, the principal opening is a 40-foot crosscut tunnel on the south lode, mostly in the limestone. The north or main contact lode, regarded as the extension of the Rattler lode, has a width of about 25 feet and consists mostly of a brownish to greenish gangue of axinite, garnet, and chloropal, with a good carbonate and copper oxide ore.

One of the most important showings on this part of the contact zone seems to be that of the Mammoth. It is about 3 miles west of Old Contact, at the head of Bluejay Gulch, on the open, steep slope of Ellen D. Mountain, at an elevation of about 7,200 feet. This claim, with several others to the east, was located about 1896 by Mr. Bourne, father of D. A. Bourne, of Jarbidge. The principal opening is a 60-foot shaft on the south contact, or lode, which has a width of about 20 feet and dips normally outward to the north. The shaft inclines 60° N. It starts in the hanging-wall side of the lode and strikes the granodiorite footwall at a depth of about 60 feet, whence downward there seems to be a decrease in angle of dip, which apparently tends to conform with the gentler dip of the rocks to the north in the mountain.

The deposit consists principally of a brownish and greenish oxidized massive axinite-garnet-quartz-chloropal gangue thoroughly penetrated by bornite, chalcopyrite, chalcocite, copper carbonates, chrysocolla, and some associated molybdenite. The ore favors the inner, footwall, or more massive granodiorite side of the lode, and here later developments are said to show that the deposit in depth becomes more permeated with bornite. The outcrop or capping to the depth of 3 feet is particularly garnetized. About 75 tons of 7 per cent copper ore lies on the dump.

Higher on the slope, to the northwest, about 400 feet from the main contact on which the 60-foot shaft above described is sunk, is another deposit exposed by a cut-short tunnel-winze opening (Pl. XXV, *B*, p. 152) showing a lode width of 20 feet. The structure dips normally

25° N. and the lode carries the usual ore minerals, especially the copper carbonates and oxides, contained in a massive garnetiferous gangue in darkish or blue country-rock limestone.

Adjoining the Mammoth ground on the west, on the main contact, is the Blue Lode claim containing a lode 20 feet wide on the contact of granodiorite and hard limestone, with associated siliceous syenitic dikes. It is opened by a 40-foot crosscut tunnel and a 20-foot shaft. The deposit consists principally of garnetiferous-looking gangue containing the usual ore minerals, which, however, do not seem to be strong in copper, 20 tons on the dump being reported to average about 5 per cent.

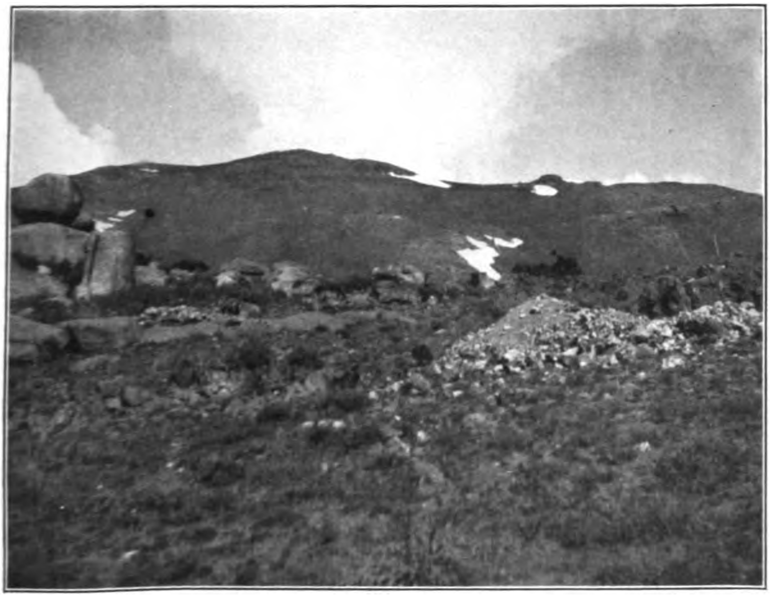
Of the transverse deposits, usually veinlike or dikelike in character, which are more or less indirectly associated with the contact zone in this part of the field, those of the Junction and New York groups, which lie in the granodiorite, may be mentioned. The so-called Junction vein, as shown on Plates XIX and XXII, starts on or near the main line of contact on the Maggie ground, and extends in a southwesterly direction continuously, it is said, for more than 2 miles to the west-side contact at the north end of the Ivy Wilson group. It is from 2 to 4 feet in width, is usually well banded, dips about 65° SE., and is associated with siliceous syenitic dikes. It is said to carry considerable good ore, much of it averaging about 25 per cent in copper.

Some outcrops and an opening on the New York vein, which is said to be similar to the Junction vein, are shown in Plate XXIV, *A*.

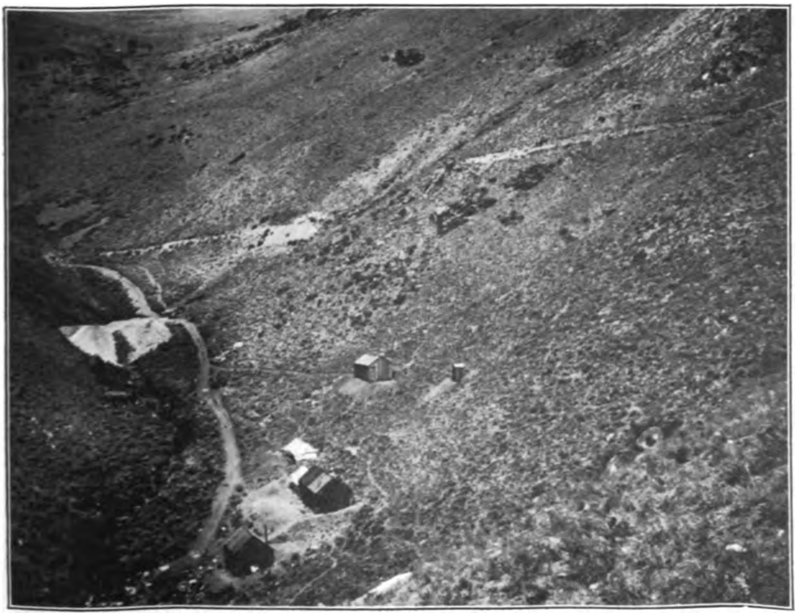
BONANZA MINE.

The Bonanza mine is situated about 4 miles west of Old Contact, in Bonanza Canyon, which drains the southwestern slope of Ellen D. Mountain into Salmon River. (See Pls. XIV, p. 100; XXIV, *B*.) Although the canyon has a depth of several hundred feet, it is generally V-shaped and the topography is not rugged. The mine and camp are reached by a wagon road of easy grade. The mine is among the early discoveries of the district. It was located in 1896 as the Dolly B. by Messrs. Coleman (locator of the Father de Smet mine in the Black Hills), Moore, and Thompson. The property comprises a group of 14 claims and several fractions, all surveyed, as shown on Plate XIX. It is owned by Samuel J. Sneider, of Minneapolis, Minn., by whom most of the development work was recently done. A small force of men was at work in the summer of 1910. The developments comprise about 500 feet of tunnel or drift, two shafts 60 and 45 feet deep, a 50-foot and an 80-foot winze, a 100-foot and a 45-foot crosscut, and a 50-foot upraise.

Owing to the location of the mine in the canyon, a valuable feature in obtaining depth on the deposits by tunnels or drifts, instead of



A. NEW YORK VEIN OUTCROP AND OPENINGS, LOOKING NORTH.



B. BONANZA MINE AND CAMP IN BONANZA GULCH, LOOKING N. 20° E.

the more expensive method of sinking shafts, the work is distributed through a vertical range of about 350 feet, from an elevation of about 7,100 feet in the bottom of the canyon to 7,450 feet on the ridge to the east.

The property is mainly on the contact of granodiorite and Paleozoic rock at the western extremity of the granodiorite batholith, which at this point, by reason of the gentle northerly dip of the contact and the depth of the canyon that cuts across it, forms an upstream embayment of the granodiorite in the sedimentary rocks.

Except about 400 feet of limestone next to the granodiorite at the base of the section, the sedimentary rocks seem to be mainly dark quartzite or siliceous slate. The principal openings are near the apex of the embayment or arc in the bottom of the canyon near camp (Pl. XXIV, *B*). Here the two lower tunnels are driven, one to the northeast and one to the northwest, both chiefly in the granodiorite. The east tunnel has a length of about 225 feet, the last 30 feet lying beyond the contact in dark limestone, which is timbered. At the face the tunnel contains a 50-foot winze, from the bottom of which extends a 100-foot crosscut in a northerly direction, with a 10-foot lode of 2 per cent copper ore, consisting chiefly of bornite and chalcopyrite in a dull greenish and brownish gray siliceous and garnetiferous hard massive gangue. Some ore, consisting mostly of malachite and bornite in 6 to 8 inch bodies, occurs also in the winze just beyond the contact, which is slickensided and barren.

On the opposite side of the canyon the west tunnel, which is 202 feet long, strikes the contact at about 114 feet from the portal. At this point there is an 80-foot winze with carbonate and oxide ore and a 40-foot crosscut driven farther into the limestone with a body of sulphide ore dipping 20° N. At the face of the tunnel there is a 50-foot upraise with an 8-foot bed of carbonate and sulphide ore in a hard gangue composed of siliceous dendritic hematite, massive garnet, quartz, calcite, and chloropal, which in places is profusely and finely seamed or veined with secondary calcite.

From the exposures in these two tunnels there seem therefore to be at least two separate lodes or ore bodies in the mine, and these lodes seem to occur also, in part, at least, in the upper workings.

In the upper west workings an inclined winze shows about a 10-foot lode or bed of low-grade ore dipping gently to the northwest, which by replacement seems to have penetrated the medium or heavy bedded limestone. It consists mostly of copper carbonates, oxides, and sulphides, with associated molybdenite, in a garnetiferous gangue. The footwall or underlying limestone is irregularly crushed, crudely bedded, and highly stained yellowish, greenish, and black by iron, manganese, chloropal, garnet, and associated green and blue copper carbonates.

The upper east tunnel, which is about 75 feet above the lower tunnel and just above the road, extends northeastward for 60 feet, chiefly in whitish limestone which dips 30° to 40° W. At the portal this tunnel shows the 20-foot mineralized "lead" or lode, which is reported to average about 4 per cent in copper. A carload of the ore, presumably sorted, shipped to Salt Lake, yielded 24 per cent of copper. The lode at this point is traversed diagonally by a dark, medium-grained, moderately porphyritic dike 4 to 8 feet wide which seems to stand near monzonite and which also, as a result of replacement, contains good ore. This dike in general is said to accompany the contact zone in a similar manner across the Bonanza group, particularly west of the canyon, where it shows a darker phase.

At the top of the ridge east of the mine, about 350 feet above the lower workings, on claim No. 2, the contact croppings, opened by a series of shallow en échelon open cuts, show a mineralized zone about 40 feet in width, or 60 feet across the surface, composed of nine or ten members, including several porphyritic dikes. The gangue is in general siliceous and garnetiferous and in certain members, notably in those favoring the granodiorite side, it is sparingly ore bearing, the usual copper carbonate and sulphide minerals being conspicuously present.

In the southwestern part of the property, on claim No. 4, in the contact zone, a 60-foot shaft is said to show a "vein" containing about 5 feet of sulphide ore in a mixed siliceous garnetiferous gangue, with well-defined walls. The dip is outward or normal, to the west, and is steep, as the contact steepens after leaving the mine, as it curves and goes south.

Striking about north and south through the Bonanza Fraction claim, in the granodiorite, is a reported fissure vein 30 inches wide with a quartz gangue, dipping steeply to the west and carrying considerable copper ore, mostly in the carbonate form and averaging about 25 per cent in copper. It is in line with the mine, where it has apparently not yet been observed and may lie buried in the bottom of the canyon. Claims Nos. 3, 5, and 6, to the east, are said to be located on similar fissure veins, all in granodiorite and trending northward, at about right angles to the contact. Claim No. 7 is said to contain a similar 30-inch fissure vein dipping southwestward in a large lode and is opened by a 15-foot shaft.

About one-fifth of a mile southwest of the Bonanza mine and camp, south of the point where the wagon road crosses the ridge, the granodiorite is intruded by a stock of the whitish siliceous syenite or aplitic rock that appears to form the prominent butte or knob studding the ridge at that point, and it seems probable that the fissure veins above described, whether associated with dikes or not, may be genetically connected with this siliceous intrusive rock, as are probably the Poole, Shield, and other dikes and veins on the Salt Lake and neighboring ground southwest of the town.

IVY WILSON GROUP.

The Ivy Wilson group is located on the western contact zone, 5 miles southwest of Contact, in the western part of the area. It is chiefly on the southern part of the long, sloping ridge that extends from Ellen D. Mountain southward to the river, between Salmon River on the southwest and Thompson Gulch on the northeast.

The property is about one-third of a mile wide, trends in a northwest-southeast direction for a distance of nearly 2 miles, and ranges from about 5,500 to 6,700 feet in elevation. The camp, commonly known as the United States camp, is located three-fourths of a mile to the east, at a spring, on a line of claims known as the White Elephant claims, which follow mineral-bearing syenite dikes in the granodiorite. These dikes dip northwest. Associated with them in places are veins or other mineral deposits. For instance, on the White Elephant No. 1 claim is a small vein composed chiefly of copper carbonate.

The topography is rough but not rugged. The ground is easy of access. It was discovered and partly staked about 1880, and was located by W. T. McArdle, of Contact, the present owner, in 1895, about which time it supplied some ore to the Contact smelter. Very little substantial work was done, however, until recently, when the property was taken over by the United States Mining Co., of Salt Lake, which has steadily prosecuted development work and at the time of visit was operating with a party of 15 men. The company expects to continue operations for some time to come.

The property comprises a group of 22 surveyed claims (Pl. XIX, p. 112), the openings or prospects on which are commonly referred to collectively as the McArdle mines. It is developed principally by four tunnels aggregating 1,100 feet, of which the longest is 400 feet and the shortest 160 feet long. The production, which was not learned, can not have been large.

The property is located principally on the west or outer side of the contact zone of the granodiorite intruded into the Paleozoic limestone and other Paleozoic sedimentary rocks. These limestones, next to the contact, form a north-south belt having a known width of about three-fourths of a mile, and for the first 1,200 or 1,500 feet the beds are on edge or steeply upturned and in general highly altered by contact metamorphism, being in some places completely marmarized and in others almost wholly changed to diopside and other minerals. Locally, the beds are crushed and slickensided and show considerable disturbance. They are generally, in places profusely, intruded by granodiorite and syenite sheets, dikes, and masses. These intrusions are particularly plentiful on the Ivy Wilson claims Nos. 3 and 4, where the limestone in the top of the hill is intercalated or ribbed with them.

The contact approximately follows the ridge, which is relatively steep faced on the east or inner side, but slopes more gently toward Salmon River on the west or outer side.

The deposits are principally of the contact-metamorphic and replacement types and occur mainly on the sedimentary side of the contact zone, but they are less closely confined to the contact than the deposits heretofore described, being more widely and sporadically distributed in the limestone in a belt 1,200 feet or more wide. The greater width of this belt and the greater degree of metamorphism may be due in some measure to the fact that the zone here lies about 1,000 feet lower than it does on the north and was probably about this amount more deeply buried at the time of the intrusion.

Ivy Wilson claim No. 9, situated on the contact near the middle of the group, is opened principally by what is known as the granite tunnel and a shaft. The tunnel has a length of 260 feet and a maximum depth of several hundred feet at the axis of the ridge it undercuts. The first 200 feet lie in the granodiorite and the remainder in limestone. The limestone is more or less crystalline, silicified, and slightly garnetized, and most of it is so completely crushed that the structure of the beds is not determinable. The contact, however, dips about 80° abnormally, in toward the basin, and its crushed and slickensided condition shows it to be much disturbed and more or less faulted. At about 150 feet in from the portal the limestone is cut by a 1-foot dike of the fine-grained phase of the syenite dipping 25° E. into the basin.

At and in the shaft, which is several hundred feet above the tunnel, the limestone dips 65° outward, to the west-southwest, and exposes a partly mineralized lode (?) 8 feet wide, containing several 4-inch stringers of copper carbonate alternating with 6 to 8 inch bands of garnetiferous rock or gangue, but the lode does not seem to connect with the garnetiferous band in the crest of the ridge over the tunnel. The limestone here is more or less crystalline, silicified, and otherwise altered by metamorphism to very fine grained or dense light-colored aphanitic silicate rock resembling quartzite, flint, or chert.

The old-time shaft on Ivy Wilson claim No. 5, which contributed ore to the Contact smelter some years ago, has a depth of 60 feet, of which 40 feet is in a mineralized brecciated zone of dark country-rock granodiorite, with which is associated a 15-inch dike of partly mineralized syenite porphyry.

On Ivy Wilson claim No. 1, among other openings, is a 40-foot shaft and below it a 400-foot tunnel showing a 40-foot lens or bed of low-grade ore. The shaft shows also iron-capped carbonates on a 4-foot vein (?) or mineral band containing also other copper-ore minerals. The tunnel is mostly in limestone and beneath the shaft shows the 40-foot lens of low-grade copper ore with a little asbestos in a blackish garnetiferous gangue.

A 15-foot shaft on Ivy Wilson claim No. 4 opens a good-looking cross-fissure vein which has been traced westward for more than 200 feet and seems to be among the best showings of the group.

On Ivy Wilson claim No. 8, in metamorphosed limestone at about 500 feet from the contact, occurs a peculiar deposit of copper-pitch ore or impure chrysocolla consisting apparently of a breccia of dark-brown or blackish siliceous copper-bearing hematite of vitreous luster, the fragments of which are firmly cemented, principally with impure chrysocolla, and which contains, besides disseminated chalcopyrite, copper in chemical combination with the hematite. The deposit is massive and contains angular druses nearly an inch in maximum diameter lined with finely crystalline silica. A 30-foot shaft sunk on the deposit is reported to be all in good ore, which is said to be very hard to drill. There are no outcrops or surface features to indicate the lateral extent of the deposit, but, although it appears chimney-like, it probably follows a fault plane or the bedding of the limestone for some distance.

An interesting and seemingly important feature of the group is the so-called sulphide zone, which is about 400 feet wide and extends through the western tier of claims for about 6,000 feet. It lies about 1,200 feet west of the contact, with which it is about parallel, and it follows the strike of the rocks, which are mostly on edge or highly tilted. The rocks consist chiefly of limestone altered by contact metamorphism, are moderately garnetiferous, silicified, silicated, hard, and mostly massive, and seem to contain the other usual minerals—axinite, epidote, chloropal, diopside, limonite. In this zone the principal ore mineral is chalcopyrite, usually with some associated molybdenite and bornite. It is more or less widely disseminated throughout the rock but with some degree of concentration in certain bands or areas, examples of which are described below.

A 15-foot "sulphide" shaft on the north end of the Dallas claim No. 3 shows about 6 feet of solid massive greenish-gray mineralized limestone in a single bed which dips steeply in or stands vertical and is thoroughly disseminated with chalcopyrite.

The 50-foot crosscut "sulphide" tunnel on Dallas claim No. 4, which is in slate-colored slaty limestone, at about 25 feet from the portal cuts a 1-foot band of soft mineralized rock containing, among other minerals, copper carbonates, some chalcopyrite, and a little bornite; also lenses or portions of the harder rock contain some disseminated copper sulphides.

About 200 yards north of the "sulphide" tunnel occurs a bed of bluish-gray quartzite (?) 1 to 3 feet thick, which is more or less garnetiferous and contains disseminated molybdenite. The rocks on either side of this bed contain disseminated chalcopyrite and bornite.

COPPER SHIELD AND NEIGHBORING GROUPS.

Extending from the Ivy Wilson group in an east-northeast direction across Thompson and Bluejay gulches through the granodiorite to a point within a mile or two of Contact and the river are 10 or more fissures containing chiefly syenitic and quartz monzonite porphyry dikes which are locally mineral bearing and on which, as shown on the claim map (Pl. XIX, p. 112), are located the Copper Shield or Effie Fay, Florence, Salt Lake, Blue Rock, and other groups. Though the surface is locally rough or bowldery, the area as a whole is easy of access.

At about the middle part of their courses the dikes are crossed by Bluejay Gulch, to the west of which they are said to dip steeply northward toward the contact, while to the east of the gulch they dip steeply southward, a fact which suggests that the gulch here probably lies on a fault line.

The mineral in some places is contained in quartz veins associated with the dikes (see Pl. XXIII, *A*, p. 118) but elsewhere occurs as replacement or segregation deposits in the dikes themselves. A few examples of these deposits are described below. The croppings of the larger fissures are usually the quartz syenite porphyry; those of many of the smaller fissures are cappings of oxidized ore and vein material.

FLORENCE GROUP.

The Florence group is composed of a dozen or more claims owned by the Maine Contact Copper Co. On claim No. 7, opened by a shaft, a 3 to 5 foot light-colored medium-grained syenite dike lying between sharply defined granodiorite walls contains copper carbonates, oxides, and some sulphides distributed or scattered in stringers or stringer-like lenses of quartz, mostly toward the sides or walls. At about 150 feet to the east a 60-foot shaft shows some good ore in place and some on the dump, and a streak of this ore is said to extend all the way down in the shaft. Here the dike has a width of about 8 feet.

On the adjoining Portland claim, to the north, owned by Hickey, Klitz & McShane, of Contact, a similar parallel dike or vein, 4 feet or more in width, with sharply defined walls, consists mostly of copper-bearing cobbly quartz fragments and bowlders contained in a seemingly decomposed granitic matrix (Pl. XXIII, *A*).

To the east, on Florence claim No. 16, one-eighth of a mile west of Bluejay Gulch, the dike, which is opened by a 20-foot shaft, contains carbonates, oxides, chrysocolla, and also the sulphides of copper in a gangue of glassy quartz and dark-brownish siliceous hematite, with considerable associated flaky molybdenite in the more hematitic portion.

To the east of Bluejay Gulch Florence claim No. 13, opened by a 30-foot shaft for 20 feet or more down, shows a 1½-foot vein of good-looking ore similar to that just described. This vein is confined by the dike rock a foot or more in thickness on either side, outside of which, on the south or hanging-wall side, the granodiorite rock is considerably crushed. A large "bowlder" of the ore from this opening is said to have attracted considerable attention at the Alaska-Yukon-Pacific Exposition.

COPPER SHIELD GROUP.

Northeast of the Florence group is the Copper Shield or Effie Fay group, consisting of 11 claims owned by the Copper Shield Copper Co. It contains a large dike which, where observed on the western part of the ground in a crosscut tunnel, shows a width of more than 50 feet with the south wall not exposed and contains a small amount of copper carbonates. The dike to the east of this point is reported to be 200 feet in width and in places carries copper ore, including bornite, all the way across.

In the southern part of the group, at the Shield house, in a 30-foot shaft and well, a 3½ to 4 foot dike contains ore nearly all the way across, and a large bowlder like part of the ledge outcrops 5 feet high in an adjoining pit. The ore has a good-looking siliceous hematite and quartz gangue, is crudely banded, and somewhat crushed. The ore minerals are principally the copper carbonates and oxides, with the sulphides, bornite and chalcopyrite. With the ore are associated some specularite and molybdenite.

SALT LAKE GROUP.

Joining the Copper Shield group on the south is the Salt Lake group of 16 claims, owned by J. H. Raleigh, of Salt Lake. The claims are all located on mineralized dikes or veins and show ore. On claim No. 5, a 50-foot tunnel shows 18 inches of ore in the face. On claim No. 7, on a syenite dike 60 feet wide, a 15-foot shaft shows about 3 feet of ore said to average about 6 per cent in copper.

In the southern part of the group the ore in places is said to be of considerably better grade, much of it going about 20 per cent, with the porphyry in general well stained with copper. Here on claim No. 9, on the Poole dike, which is syenite porphyry and which has a width of more than 100 feet, a 10-foot shaft shows a well-banded 6-inch vein of copper oxide and carbonate ore with a siliceous hematite and quartz gangue. This vein or dike is said to extend southwestward for more than 3 miles to the Ivy Wilson ground.

YELLOW GIRL MINE.

The Yellow Girl claim adjoins the Salt Lake group on the southwest. It is patented and said to be held at $100,000. Where the Poole dike is opened by a 200-foot shaft, it rapidly widens from the 60-foot level downward, and on the 200-foot level, where it has been crosscut for 38 feet with no wall yet reached, it is said to carry 6 feet of 12 per cent copper ore, similar to that on Salt Lake claim No. 9, described above, and about 32 feet of low-grade ore.

HICKEY PROSPECT.[1]

Among the outlying prospects of the Ellen D. Mountain area should be mentioned the Hickey prospect, owned by M. F. Hickey, of Contact. This is commonly known as the Lead-Silver mine. It is located about a mile northwest of Old Contact, in the second gulch, a locality which seems to be mineralogically an interesting part of the district.

The country rock is said to be the dark or blue limestone. The developments consist principally of a short tunnel and an upraise from which relatively considerable lead-silver ore of fair grade has been taken out.

The deposits are contained in two or more veins which trend in an east-west direction with nearly vertical dip and seem to be more or less associated with porphyry dikes or other intrusions, near which there is a reported improvement in the quality and increase in quantity of the ore.

The mineralization, to judge from the ore specimens examined, seems to have resulted from a process of replacement in a finely comminuted fault breccia. The ore minerals are those of silver, copper, lead, and gold, and the ore seems to consist of two principal types, known as cerusite ore, which is a yellowish lead carbonate, and "binoxide" ore, which is brownish red and seems to consist principally of the oxides of iron, lead, and copper.

The principal vein is about 3 feet in width and contains chiefly cerusite ore. The other vein consists chiefly of binoxide ore. Silver, seemingly as argentite, is present in both veins, but it occurs chiefly in the cerusite ore, where it amounts to as much as 92 ounces to the ton. The gold, on the other hand, occurs chiefly in the binoxide ore of the smaller vein, where it averages about $4 to the ton.

CHINA MOUNTAIN AREA.

LOCATION AND GENERAL FEATURES.

The China Mountain area almost joins the Ellen D. area on the southeast, lying on the other side of Salmon River. It centers near

---

[1] For information on this property and for specimens, the writer is indebted to Messrs. D. C. McIntyre and M. F. Hickey.

China Mountain, about 5 miles south-southeast of Contact. (See Pl. XIV, p. 100.) It is contained in an area 4 miles wide and 5 miles long, extending from the head of Meadow Creek and McDuffy Gulch southward toward Knoll Creek. From an elevation of less than 5,400 feet at the river the surface, which is generally rough, rises above 8,000 feet in China Mountain, whence it declines in all directions to the borders of the area.

Both the granodiorite and the Paleozoic sedimentary rock types of topography are present. The latter, which comprises the dominant features and especially characterizes the southern part of the area, including the large rounding mass culminating in China Mountain, is illustrated in Plate XVI (p. 100). The area, however, is generally accessible. It is nearly encircled by a wagon road, and by means of certain gulches on the northwest can be penetrated by wagon to points within a mile of the top of the mountain.

The country rock is the granodiorite on the north and the Paleozoic sedimentary rocks on the south. The two are separated by the usual well-defined east-west contact, which, as shown on Plate XIV, crosses China Mountain and the highest near-by peaks almost at their summits, but these summits, as at Ellen D. Mountain and elsewhere, are all situated to the sedimentary side of the contact. The sedimentary beds, though variously deformed, in general dip toward the south, or away from the contact, along which their upturned edges form a hogback-like scarp overlooking the lower-lying granodiorite area within the basin.

At China Mountain in 1876 apparently the earliest substantial work in the district was done by a group of Chinamen employed by an official of the Southern Pacific Co. Seized with superstition by the illness and death of one of its members, the party abandoned the work in the midwinter and traveled on foot to Wells, after which the ground lay idle till late in the eighties.

The deposits are similar to most of those in the Ellen D. Mountain area, described above. Their general distribution is indicated by the mine and prospect symbols on Plate XIV (p. 100) and by the location of the claims as given on Plate XX (p. 112). They occur mostly in association with the granodiorite and Paleozoic rock contact zone, which in places has a width of nearly 2,000 feet. The Hanks-Miller-Leach group[1] of claims and the Chinaman group, trending respectively northeasterly and easterly, are in this zone, but the inlying groups to the north of this and trending more nearly north and south, at about right angles to the contact, are in the granodiorite and comprise deposits of the dike-vein class.

---

[1] This term is here used for convenience of reference and does not necessarily imply ownership in common.

The principal openings are the so-called Chinaman, War Eagle, Hanks, Turo-Sheckles, and High Ore mines, which, however, are for the most part still in the prospect stage.

CHINAMAN MINE.

The Chinaman mine is in the upper northwesterly slope of China Mountain, at an elevation of about 7,700 feet. It is on the Skylark claim No. 1, one of a group of six claims (the Chinaman group, Pl. XX, p. 112) located by W. T. McArdle in 1895, about 20 years after the ground had been prospected and deserted by the Chinese party, as above described. The group is owned by Messrs. Lumm, Morling, Pritchard, and McArdle. It extends from a point above the mine down along the contact zone for about 1½ miles, nearly to the base of the mountain and the river on the west. The topography in the upper part of the group is rugged and the mine is not easy of access. It is reached by trail only, for which reason operations have recently been begun on the lower end of the group on Copper Mountain Claim No. 1, nearly 2,000 feet lower, where the deposits are more accessible, and a tunnel, now in 50 feet, is being driven.

The mine is located near the head of a gulch, on the limestone side of the contact. Sheets or dikes of granodiorite, the thinnest 3 feet in width, are intercalated in the limestone, and quartz syenite porphyry dikes of the aplitic phase, described on page 111, are associated with the deposits.

The deposits are opened principally by a short tunnel or drift, a crosscut, and a 50-foot winze. They are contained in a lode or mineralized band about 22 feet in width, with some ore distributed nearly all the way across. The dip is about 75° away from the contact, and at about 12 feet in from the portal of the tunnel the ledge is cross faulted at nearly right angles by a southward-dipping fault plane showing slickensides, etc.

A partial section of the lode, beginning with the granodiorite country-rock footwall on the north, is as follows:

Partial section of lode in Chinaman mine.

Granodiorite.	Feet.
Aplitic dike	3
Limestone, light and in part siliceous	1½
Banded copper ore in the usual siliceous chloropal-garnet gangue	5

The ore consists mostly of carbonates. About 80 tons of 14 per cent ore, remaining from a heap of which a test was made at the Contact smelter, lies on the dump.

WAR EAGLE MINE.

The Hanks-Miller-Leach group comprises 27 or more claims extending, three deep, from the summit of China Mountain southeastward on the contact zone down the slope for a distance of nearly 3 miles. The contact approximately follows the median line of the northeast tier of claims, the Defender, New Years, and others. Of this group the nine end claims on the southeast, owned by J. W. Hanks, are known as the Hanks group. They were located in 1887 for copper by a German who bonded the property to an English company. Later the ground was several times relocated by others, among whom W. T. McArdle, in 1895–96, mined and shipped 8 carloads of copper ore that averaged about 24 per cent of copper, 14 ounces of silver to the ton, and about 7 per cent of silica; one of these carloads is said to have averaged 33⅓ per cent of copper.

Five of the claims indicated on Plate XX (p. 112) are surveyed and patented ground, and the principal openings on them, notably the War Eagle, Turo-Sheckles, and Turo, are known as the Hanks mines. They seem to be among the most important in the area. The topography is rough but not rugged. Its character is shown in Plate XVI, *A* (p. 100).

The War Eagle mine is located about 2½ miles southwest of the summit of China Mountain, on Hanks claim No. 1, at an elevation of about 7,300 feet. The mine is about 500 feet outside of the contact, on a parallel streaked or banded lode or bed 8 feet wide, carrying copper ore in a gangue of chloropal, jaspery quartz, axinite, and garnet in dark limestone country rock with 40 feet of silicified limestone or quartzite on the inner or hanging-wall side. Siliceous syenitic dikes occur near by—for instance, in the saddle at the location stake about 200 feet to the northwest. The lode is open mainly by an inclined shaft 120 feet deep, and a 75-foot drift to the northwest on the 25-foot level with a 40-foot upraise at the end.

The work was nearly all done in 1895 and 1896 by W. T. McArdle. To a depth of 100 feet the lode is said to dip 70° in toward the contact, but from this point downward it gradually straightens and is thought to turn over and dip normally outward, like the Brooklyn vein. The mine was last worked in 1899. About 100 tons of the ore now on the dump is said to average 7 per cent of copper and about 4 ounces in silver to the ton. It consists chiefly of copper carbonates and oxide, with a little copper sulphide.

TURO-SHECKLES MINE.

The Turo-Sheckles mine is about half a mile northwest (up the slope) from the War Eagle mine, on the Rochester claim, at an elevation of about 7,600 feet. It is located at about 900 feet outside of the contact, on a parallel ledge or ore bed in whitish limestone. Both the ledge and the limestone have a steep normal dip outward toward the south. Dikes of quartz syenite porphyry are intruded within 30 feet of the ledge on the north. The ledge is opened by a

120-foot shaft which shows neither wall but in which no crosscutting has yet been done.

The ore is mostly carbonate and oxide of copper, with some sulphide in depth. Three carloads of the ore were shipped. They contained 18, 24, and 32 per cent of copper, and averaged 7 ounces in silver to the ton. About 75 tons of 12 per cent copper ore and 450 tons of 6 per cent ore lie on the dump.

TURO MINE.

The Turo mine is about 200 yards southwest of the opening last described, at an elevation of about 7,600 feet, on the Lincoln claim, which joins the Rochester on the southwest. It is on what is known as the Hanks vein, which lies conformably in vertical dark country-rock limestone, is 12 feet wide, and contains principally carbonate and oxide copper ore in a bowldery-like garnetiferous gangue with some included limestone. It is opened by an 80-foot shaft, which is now considerably caved. About 60 tons of 12 per cent copper ore is on the dump.

HIGH ORE MINE.

Of the vein or " dike-vein " deposits in this area, all in the granodiorite, the most important are those of the High Ore mine and Camp Bird prospect. Practically all the veins or dikes observed trend northeastward, roughly parallel with those in the Ellen D. Mountain area west of the river, and seem to belong to the same fissure system.

The High Ore mine is about a mile northeast of China Mountain and the contact, at the head of Meadow Creek, at an elevation of about 6,800 feet, in open country, and is easy of access. It was exploited in the middle seventies by the same persons who then worked the Chinamen mine. The property comprises a group of six claims. It is opened chiefly by an old 65-foot inclined shaft sunk on a vein which dips 45° W., and sems to be contained in a quartz monzonite porphyry dike similar to that of the Camp Bird prospect next to be described. Owing to a cave-in, the shaft could not be entered, but to judge from blocks of ore seen on the ground the vein has a width of at least a foot and consists of about 9 inches of ore with 1 or 2 inches of quartz gangue on either side. The ore consists of red copper oxides, carbonates, and sulphides in a siliceous gangue. The run-of-mine ore is said to average about 16 per cent of copper and the high grade 40 per cent. The ground in the vicinity of the property seems to be all staked.

CAMP BIRD PROSPECT.

The Camp Bird prospect is about a mile north of the High Ore mine, 5 miles southeast of Contact and about 1½ miles northeast of

China Mountain, at the head of McDuffy Gulch, on open ground, at an elevation of about 6,800 feet. The property comprises a group of six or more claims on or near the low divide which it nearly parallels between McDuffy Gulch on the west and Meadow Creek on the east. It was located about 1907. The country rock is the granodiorite. The principal opening is a 40-foot shaft on claim No. 2 in a quartz monzonite porphyry dike which is more than 200 feet in maximum width and is said to extend on the southwest to China Mountain and the contact. It seems to fill a compound fissure or sort of shear zone and locally contains horses, lenses, vertical sheets, or bands of the country-rock granodiorite, as shown in prospect pits to the south on claim No. 3 and other ground.

In the 40-foot shaft the dike rock seems to be oxidized all the way down, and in the lower part to be generally impregnated with disseminated pyrite and chalcopyrite.

The ore consists of malachite, azurite, chrysocolla, chalcopyrite, and bornite. It occurs to some extent sporadically in the body of the dike rock itself, but more generally in and associated with parallel bands and stringers or lenses of quartz traversing the dike, some of which are 3 to 4 inches in width and alternate with bands of the dike rock. Many of the smaller stringers are comby. Associated with the ore in places as gangue is also considerable siliceous hematite.

The dike is shown by microscopic examination to consist of about 40 per cent each of orthoclase and plagioclase and 20 per cent of quartz, almost no bisilicates being present. Both feldspars are considerably sericitized, and considerable rutile and apatite are present as accessories.

The deposits on the half dozen or more neighboring groups of claims are said to be similar to those of the Camp Bird. The deposit on the Haskney-Shoun property, about 1½ miles to the west, is opened by a 25-foot 60° W. inclined shaft and shows some malachite and sulphide ore. The Warsaw-June group, to the northwest, on Warsaw claim No. 2, is said to be traversed by a vein several feet wide containing three 2-inch bands or shoots of rich ore, spaced about a foot apart. From samples furnished to the writer, this ore seems to be chiefly chalcocite, with some carbonate.

BLANCHARD MOUNTAIN AREA.

LOCATION AND GENERAL FEATURES.

The Blanchard Mountain area joins the China Mountain area on the east. It is about 4 miles in diameter and centers at Blanchard Mountain, which rises to an elevation of about 8,800 feet. From the summit the surface, which is usually not rough, declines, for the most part gently in all directions—to Trout Creek, at about 6,000 feet, on the north and east, and to Knoll Creek, at about the same elevation, on the south. On the northeast, however, is a prominent hill a few hundred feet in height, which, from the name of the property located on it, may be called Johnson Hill.

The geology is similar to that in the China Mountain area already described. The country rock is the intrusive granodiorite on the northwest, and it is embayed by an open crescent of the Paleozoic sedimentary rocks on the southeast. The general course of the contact is northeastward, in the form of a curve open to the northwest. As usual, it crosses the peaks, Blanchard Mountain and Johnson Hill, near their summits, on the upper, granodiorite, or basin side. On the upper southwest slope of Johnson Hill the contact swings or is offset to the south, seemingly by a fault of about 500 feet lateral throw, as indicated on the map.

In the Blanchard Mountain portion of the area the formations and the deposits are traversed by the usual dikes of syenite porphyry, local masses of which seem to occur in a prominent twin-peaked spur of Blanchard Mountain on the north, known as Twin Buttes. This spur appears to contain an inlier of Paleozoic quartzite.

The general distribution of the deposits is indicated on Plates XIV (p. 100) and XX (p. 112). They lie principally in the contact zone and the most important showing is on the Zetta Blanchard group.

ZETTA BLANCHARD GROUP.

The Zetta Blanchard group consists of a linear group of eight or more claims covering an extent of nearly 2 miles in the contact zone on the northerly slope of Blanchard Mountain. From claim No. 8, at an elevation of about 6,800 feet on the east slope, to No. 4, on the upper north slope, it has a vertical range of nearly 1,000 feet. It was mostly discovered and located by W. T. McArdle in 1895. The deposits so far as exploited seem to be of the contact-metamorphic type and they occur in a mineralized band or lode about 25 feet or more in maximum width on the granodiorite-limestone contact, where they have been opened at several places by shafts, tunnels, drifts, and cuts aggregating about 400 feet of work. The dip is at a steep angle conformable with the limestone and is normal, being outward.

The ore in general consists of carbonates, oxides, and the common sulphides of copper and a little chrysocolla contained in a garnetiferous gangue of chloropal, siliceous hematite, limonite, and axinite, with glassy quartz present in places. Axinite is particularly plentiful in the Zetta Blanchard gangue. The microscope shows a section from shaft No. 5 to contain about 80 per cent of axinite.

On claim No. 8, in the east slope of the mountain, at an elevation of about 6,950 feet, the lode is opened by a 60-foot "tunnel," or drift, run westward in the garnetiferous chloropal-axinite zone, or lode, which contains some disseminated copper ore and shows some garnetized granodiorite on the footwall and partly metamorphosed garnetized gray crushed limestone on the hanging wall.

To the west, up the slope, on claim No. 6, at an elevation of about 7,000 feet, the principal opening is a 150-foot crosscut tunnel containing about 70 feet of so-called crosscut or drift. This opening shows a 7 to 8 foot lode that contains good oxide-carbonate-sulphide copper ore, with some chrysocolla in the usual gangue, but seems to have in association considerable iron. Siliceous syenite dikes appear to be associated with the deposit.

On claim No. 5, at an elevation of about 7,670 feet, where the lode shows a width of 25 feet with dark-blue country-rock limestone on the hanging wall, the opening is a 52-foot inclined shaft in the outer or hanging-wall side of the lode, sunk in 1897, it is said, at a cost of $5,000. Copper ore, including chalcopyrite and bornite, impregnating a brownish-gray siliceous axinite gangue, appears all the way across the shaft. A thin section of the ore shows about 80 per cent of axinite.

Higher on the slope, at an elevation of about 7,850 feet, on claim No. 4, a similarly located 20-foot inclined shaft shows the westward and upward continuation of the same geologic and mineralogical conditions, but there is less display of ore, specularite is associated with the copper carbonate, and the mineral zone in general is considerably crushed by crustal disturbance. Farther west, on claims Nos. 3 to 1, where the openings are only a few feet in depth, the lode, or mineralized band, seems to narrow. On No. 3 it shows a width of about 2 feet, stands about vertical, and is confined between walls of the pressed granodiorite on the north and crushed dark limestone on the south.

JOHNSON GROUP.

The Johnson group, comprising nine or more claims, covers a considerable portion of Johnson Hill, in the northwestern part of the area, where, with the claims three deep, it extends along the contact for nearly a mile. The geologic and mineralogical conditions are essentially the northeastward continuation of those on the Zetta Blanchard group, except that a short distance back from the contact, to the south or outer side, the hill, to judge from the débris covering the surface, is mainly quartzite, much of it closely banded, and contains intrusive sheets or parallel dikes of quartz syenite porphyry and bedlike ledges of iron ore, apparently hematite, on which the two southeastern tiers of claims seem to be principally located. The property is owned by the Montilla Mining Co., of Montilla, Nev.

The principal openings are a 400-foot tunnel and a 100-foot shaft. The tunnel is located in the east base of the hill on claim No. 1, at an elevation of about 6,630 feet, and is driven westward on the granodiorite and limestone contact, which dips steeply out to the south or is vertical. The granodiorite, which in places forms a good firm footwall, is unusually dark, with far more than the ordinary amount of green hornblende, and is crushed, pressed, sheared, and schistose. The limestone is white, metamorphosed, crystalline, and banded. Both formations are cut by dikes of coarse quartz syenite porphyry younger than the shearing.

In much of its course the tunnel shows from 6 inches to 1½ feet of banded and crushed, partly mineralized rock or vein material, which, however, shows only sporadically a slight stain of copper carbonate and no trace of ore. It is said that no ore was expected in this part of the tunnel for the first 1,000 feet, or until the ground beneath the shaft or vicinity should be reached, a fact which, together with the transverse claim projecting at right angles down the northwest slope of the hill, suggests the probable presence of a transverse lode or vein in this locality, not observed by the writer.

The shaft, which is also located on the contact on the limestone side, is farther west, at an elevation of about 6,880 feet, or 250 feet above the level of the tunnel. It has a reported depth of 100 feet and, to judge from the material on the dump, is still in the oxidized zone. This material consists mostly of brownish and greenish garnetiferous gangue containing a little malachite and much yellowish-green to finch-green chloropal.

At a point on the contact about midway between the tunnel and the shaft, at an elevation of 6,780 feet, an open cut shows a 1½-foot band of crushed, partly mineralized material in the banded limestone, containing on the outer or hanging-wall side a 3-inch vein of malachite ore in a silicified garnetiferous axinite gangue.

On the upper north slope of the hill, at an elevation of 6,900 feet, an open cut shows the garnet-chloropal gangue zone or lode having a width of more than 10 feet, with the contact between the limestone and the crushed gangue sharply defined and vertical.

From the Johnson ground eastward the contact zone is said to be staked for several miles beyond Trout Creek, nearly to the crest of the H. D. Range. The most important claims in this vicinity seem to be the Leach group, which joins the Johnson group on the west and is said to show fair prospects in copper, but on which only the necessary work is done.

R. O. C. PROSPECT.

The R. O. C. prospect lies wholly within the basin and granodiorite area, about 1½ miles northwest of Blanchard Mountain, at an elevation of about 7,400 feet. It is in open country and easily accessible. It was discovered and located in 1908 by W. T. McArdle and is owned by Mr. O'Connell and others. The property comprises a group of six or more claims trending in a northeasterly direction for more than a mile. It is opened principally by several shafts, of which the deepest is 45 feet deep.

The deposits are of the dike-vein class. They are apparently replacement deposits in association with a medium or fine grained quartz syenite porphyry or aplitic dike which dips about 65° NW., and is about 6 feet in maximum width. In places the silicified dike and vein croppings stand boldly from 1 to 8 feet above the surface.

On claim No. 1 two shafts, 10 and 45 feet deep, show on the footwall side of the dike a banded vein from 6 inches to 2 feet wide, averaging about a foot, composed mostly of copper carbonates, oxides, and chalcopyrite with some gray copper mixed with iron, all contained in a quartz gangue. The ore is said to contain also considerable silver, some assays reporting as high as 38 ounces to the ton. The vein is tightly frozen to the granodiorite footwall and especially so to the dike hanging wall. To the northeast of the shaft the quartz vein is barren, is 6 inches wide, and gradually passes to the hanging-wall side of the dike, which varies down to a foot in width.

To the northeast on claim No. 2, where it is opened by an 8-foot shaft, the dike is softer and altered and contains quartz stringers and in places 3 to 4 inches of banded or streaked malachite-stained material or low-grade ore.

On claim No. 5 an inclined cut or shaft shows another copper-bearing dike, or probably a spur, to the southeast of the main dike. It is 8 feet wide, dips 60° W., and contains also considerable iron oxide.

On claim No. 3, opened by a 25-foot shaft, the showing is said to be in a cut similar to that on claim No. 1.

HICE MINE.

In connection with the Blanchard Mountain area two outlying properties, the Hice and Kratz mines, merit passing notice.

The Hice mine (see Pl. XIV, p. 100) is located 2 miles southeast of Blanchard Mountain, on the head of Knoll Creek, at an elevation of about 6,700 feet. It is among the early discoveries of the district and is developed by a 300-foot crosscut tunnel and a 30-foot shaft. The mine is in the crest of a prominent ridge (Pl. XVI, *B*, p. 100) of the Tertiary lake beds, which dip 20° to 30° NW. and strike nearly parallel with the trend of the ridge. These beds show faulting and slickensiding.

The deposits, which seem to consist principally of outcrops, occur in the upstream portion of the ridge, from the head of which the outcrops, from 10 to 30 feet or more wide, extend southwestward for nearly one-fourth of a mile, their trend diverging slightly from the axis of the ridge, so that while on the northeast they occupy the crest of the ridge, on the southwest they lap upon its southwest flank. In places they rise 8 or 10 feet above the adjacent surface underlain by the lake-bed sandstone. They appear to be portions of the crest of a reef of Paleozoic rocks that forms the core of the ridge, and protrudes through the surrounding younger sandstone at the surface.

These deposits are brown, yellowish, greenish, and blackish, or variously mottled with these colors. They are heavy and are said to contain on an average 60 per cent in lead, with 2 to 3 ounces in gold and as high as 240 ounces in silver to the ton. The lead seems to be all in the carbonate or so-called "sand carbonate" and oxide forms. No trace of galena is present.

The outcrops consist principally of mineralized faulted and brecciated material derived from the Paleozoic sedimentary rocks of the region, silicified and silicated dark and white limestone, quartzite, slate, quartz, jasper, barite, etc. The material is mostly fine, of the arenaceous type, though much of it ranges to medium or coarse. It is heterogeneously mixed, and much of it is firmly cemented. Underground, however, it seems to be in part but loosely coherent and in places to be crudely stratified or coarsely banded.

Owing to the high value of its mineral content and the amount of ore in sight in the croppings, the deposit has attracted considerable local attention, and recently the 300-foot crosscut tunnel was driven in a northwesterly direction to crosscut the ledge about 100 feet below the surface croppings. The tunnel, however, in passing beneath the outcrops and considerably beyond their zone continued uninterruptedly from the portal to the breast in the young soft sandstone only, encountering no trace of a ledge. The 30-foot shaft and other openings sunk on the croppings also seem to show no trace of the old rock formation or even solid ledge matter or sandstone, but have cut through only incoherent, partly cemented old fault breccia or partly rounded talus-like material, some dipping unconformably against the sandstone and some gently with it. These facts and the manner in which the sandstone rises on all sides of the ridge within 40 or 50 feet of the top make it seem certain that the outcrops and the underlying material in the sandstone are not in place, but are merely a cap resting upon the sandstone and have been brought there by a thrust fault or landslide, perhaps in the nature of an earthquake disturbance, which for lack of time could not be worked out on this visit.

So far as geologic and mineralogical composition is concerned the deposit gives no indication of any connection with the granodiorite and Paleozoic rock contact, whose nearest exposure on the opposite slope of Blanchard Mountain is 2 miles distant.

It is asserted by some that the parent ledge from which the outcrops have been derived is located far up the slope of Blanchard Mountain, which seems possible. Except that the H. D. Range is somewhat farther away, the deposit may equally well have come from the slope of that range on the southeast, a view which is favored by the fact that the sandstones in which it occurs are tilted up to an angle of 30° or more toward the northwest. Unless there is such a deposit on Blanchard Mountain, a remarkable feature is the absence of any such deposit anywhere else in this part of the district. The nearest known similar deposits are those of the Hickey mine, already described, 14 miles to the northwest, near Old Contact.

An alternative to the thrust-fault or landslide view is the view that the ledge or old rock core of the ridge, if such it be, of which the outcrops may represent the crest, may have been undermined, hollowed out, corroded, or eroded through after the manner of a cave or natural bridge and the opening subsequently become filled with the sediments that formed the young sandstone where the course of the tunnel now passes beneath the outcrops, which therefore at this point form a natural arch or bridge in the ridge of Paleozoic rocks.

The advisability of further prospecting the ledge by crosscuts and of sinking to determine its downward extent at various points before installing expensive machinery is obviously shown by the results obtained in the present tunnel.

KRATZ MINE.

The Kratz mine, better known as the "old Kratz" mine and the "old silver" mine, is, as shown on Plates I (p. 10) and XIV (p. 100), about 14 miles southeast of Contact and 3 miles south-southeast of the Hice mine, on the northwest slope of the H. D. Range, at an elevation of about 7,800 feet. The topography is mountainous but not rugged. The deposit was discovered and located about 1885, by Mr. Turo and his partner, who sunk an 80-foot shaft and took out some ore.

The country rock consists of the Paleozoic sedimentary rocks, and apparently a sandstone-like formation is dominant at the mine.

The deposit is said to be contained principally in a 10-foot lode of white quartz, which is traceable for 3,000 feet and is opened at several points, but on which not sufficient development work has been done to determine its value. The ore minerals are contained in an 18-inch vein or ore shoot crossing the lode. They consist chiefly of silver sulphide, and average about 40 ounces in silver to the ton, manganese, copper, lead, and zinc also being present. In the bottom of the shaft the ore carries about 4 per cent of copper, which leads to the hope that at greater depth it may be workable for copper. From portions of the vein J. F. O'Byrne reports assays running as follows: Manganese, 40 per cent; copper, 2 per cent; lead, 20 per cent; silver, 4 ounces to the ton; zinc, one-half ounce to the ton; gold, a trace.

MIDDLE STACK MOUNTAIN AND TROUT CREEK AREA.

LOCATION AND GENERAL FEATURES.

The Middle Stack Mountain and Trout Creek area lies in the northeastern part of the district, on the north contact zone. It begins at Middle Stack Mountain, 6 miles northeast of Contact, whence it extends eastward across Trout Creek for a distance of about 6 miles. The topography is mountainous and much of it rough, but it is generally not rugged. The area is reached from Contact by wagon road or trail, passing to the south of the mountain, and also by ascending Trout Creek from San Jacinto on the north. Mineral seems to have been discovered here in the sixties. The country rock is the usual intrusive granodiorite and Paleozoic sedimentary rocks, principally limestone and slate, which in general dip to the north away from the contact and with the granodiorite are intruded by syenite and monzonite dikes. The granodiorite in places shows pronounced sheeting, and at about 2 miles southeast of Middle Stack Mountain and also a few miles northeast of this point, on the contact near Clark Cabin, it is intruded by quartz syenite or quartz monzonite stocks accompanied by radial dikes.

The mineralized zone has a maximum width of about half a mile. The general distribution of the more important deposits is indicated on Plate XXI (p. 112). The deposits, except those to the west of Trout Creek, are similar to those on the contact zone described in the preceding sections, except that they are more generally associated with dikes. The usual metamorphic minerals, particularly massive garnet, chloropal, and axinite, are characteristically present in the gangue. A specimen from the Dakota shaft on the Clark group gives strong tests for boron, indicating the presence of axinite in considerable amount.

The principal properties are the Boston mine and the O'Connell, Clark, and Toano claim groups.

O'CONNELL GROUP.

The O'Connell group comprises seven or more claims, beginning on the southeast slope of Middle Stack Mountain and extending eastward along the contact for about 1½ miles. The location of these claims is indicated on Plate XXI (p. 112).

On the west, on the Daddy of Nevada claim, at an elevation of about 7,100 feet, the deposit is opened by a tunnel several hundred feet long driven in a northerly direction through sheeted granodiorite and the contact where the granodiorite is garnetized contains molybdenite, and is succeeded by garnetiferous limestone or quartzite. Both the granodiorite and the sedimentary rocks are intruded by the medium to fine grained light-colored siliceous syenite or aplitic dikes and the dump contains a small amount of good copper ore. A cut to the west of the tunnel shows 8 feet of banded greenish chloropal-garnet vein or lode material containing some mineral and with the contact between granodiorite and decayed limestone sharply defined and dipping normally 70° N., or outward.

About one-fourth mile farther west, on the Great Nevada claim, at an elevation of about 6,970 feet, a 40-foot inclined shaft is sunk in the white-limestone hanging wall of the garnetiferous lode, here 30 feet wide, granodiorite forming the footwall. The dump shows siliceous and garnetiferous banded ore.

Half a mile farther west, on the Three Links claim, at an elevation of about 6,740 feet, a tunnel starting on the sedimentary side of the contact runs S. 60° W., mainly in the garnetiferous banded gangue material, which dips abnormally 80° S. At the contact this tunnel exposes copper carbonate ore in the granodiorite. Here and in an adjoining cut to the southwest copper ore also occurs in the joint planes in the granodiorite, and in both tunnel and cut the granodiorite is traversed by dikes of medium-grained quartz syenite porphyry or aplitic rock.

About a quarter of a mile to the northeast, on the American Eagle claim, on the east end of the group, at an elevation of about 6,500 feet, one-fourth mile distant from the contact on its outer side, a dike of medium-grained pinkish monzonite porphyry cuts across the dark country-rock limestone and contains in association some malachite ore. One-eighth mile south of this point, up the hill, a 50-foot inclined shaft, seemingly in the same dike and formation, shows the mineralization much better developed. About 20 tons of siliceous copper ore, which is said to carry also considerable values in silver, is on the dump. The limestone dips normally about 45° N. The dike has been considerably shattered and is traversed by quartz veins and stringers 8 inches in maximum width.

CLARK GROUP.

The Clark group consists of six or more claims owned by George Clark, a pioneer of the district. As shown on Plate XXI (p. 112), these claims center about the Boston mine, to be described. The group joins the O'Connell group on the east, whence it extends eastward for nearly a mile, with the mineralized zone half a mile or more in width.

The contact here lies at the southern edge of the zone and follows for the most part the crest of an isolated elongated hill or ridge

(Clark Hill) several hundred feet high, rising to an elevation of about 6,550 feet. The contact zone is compound, being 150 feet or more wide, with inlying, upturned, apparently detached bands of limestone, as at Ellen D. Mountain (p. 105), and it contains the siliceous syenitic or aplitic dikes; in fact, on the southeast slope of the hill the granodiorite is intruded by a stock of a rock standing close to quartz monzonite, with which the dikes are probably connected.

The west end of the hill exposes a peculiar anticlinal structure where the upturned edges of silicified limestone or fine-grained quartzite beds, aggregating 40 feet in thickness and dipping steeply outward to the north, are met by equally steep and pronounced sheeting structures in the granodiorite and dikes dipping in the opposite direction.

The three southerly claims, the Contact, Dakota, and Minnesota, are on the contact, mostly on the hill portion. On the southwest corner of the Minnesota, at about 150 feet in from the granodiorite contact, a cut shows a parallel garnetiferous belt or lode 16 feet wide, which it is difficult to differentiate from garnetized granodiorite and altered limestone, but which, to judge from its alignment in strike with less altered beds of white limestone near by, seems to represent completely metamorphosed and mineralized limestone. Near its middle the lode contains two more completely mineralized bands, 1 or 2 feet wide, containing some malachite and a little chalcopyrite, and a short distance to the northwest of the cut the limestone is banded with parallel veinlets and stringers of quartz ranging up to 1½ inches in width.

On the Dakota claim, at an elevation of about 6,430 feet, the northwesterly side of a 12-foot shaft sunk in the granodiorite within 5 feet of the contact shows a fairly regular mineralized vein, 3½ feet wide at the top and 1½ feet wide at the bottom of the shaft, with stained garnetiferous quartz gangue containing some copper carbonates. The dip is about vertical, with granodiorite on both walls and silicified limestone or quartzite dipping 70° outward only 5 feet distant. To the northeast both the granodiorite and the sedimentary rocks are much crushed and blocky. At the northeast corner of the claim, about 200 feet northwest of the contact, is a short tunnel, which, however, shows little more than the crushed brown limestone, with coarse calcite.

About 1,500 feet outside of the contact, on the south slope of the hill to the north, on the Bridgeport claim, at an elevation of about 6,370 feet, an 8-foot inclined shaft shows a 3-foot mineralized bed in which massive garnet with considerable quartz forms the gangue in apparently alternating dark and light layers of silicated limestone. The bed contains copper carbonate, some oxide, and a little bornite.

On the Mary T. claim, joining the Bridgeport on the north, at an elevation of about 6,440 feet, a 16-foot cut exposes a 4-foot ledge which seems to be an altered dike or sheet of igneous rock that dips 70° NNW., conformably with the bedding of the dark-limestone country rock, and contains sporadically distributed malachite. About 50 feet farther down the slope another cut shows about 4 feet of good, low-grade ore with the dip of both vein and formation straightened to about vertical. Near by, on the eastern part of the southern slope of the hill, at an elevation of about 6,330 feet, to the north of the Boston mine, next to be described, occurs plentiful good-looking float, similar to the sulphide ore in the Boston mine. The float seems to be derived from outcrops not yet discovered, farther up the slope to the northwest.

BOSTON MINE.

The Boston mine, as shown on Plate XXI (p. 112), lies in the midst of the Clark group at an elevation of 6,140 feet. The claim trends to the northwest, diagonally across the gulch which separates Clark Hill on the south from higher ground on the north. Access is easiest from the southeast around the foot of Clark Hill, where there is an old wagon road over which the ore produced was hauled out.

The date of discovery was not learned, but the property was probably discovered in the early seventies, about the time the China Mountain deposits received attention. The mine was worked in the late seventies, and about 1880 it made shipments of copper ore which were hauled by ox team and wagon to Ogden, Utah, and to Tecoma, Nev., whence the ore was shipped to Swansea, Wales, and to Boston. The ground was patented in 1900 and is developed principally by a tunnel, a winze, and a shaft. The production was not learned, but probably was not large. About 40 tons of low-grade ore lies on the dump.

The mine is located about 700 feet to the north of the granodiorite contact. The country rock is the light-colored, mostly heavy-bedded Paleozoic limestone. It is uptilted and folded and at the mine dips steeply out to the northeast. No dike rocks were observed in association with it at the mine. Dike float, however, is present, and the deposit is approximately in alignment with the opening on the Mary T. claim, to the northwest, already described as being on a dike or intrusive sheet.

The deposit consists mainly of a 4-foot vein or ore bed composed principally of a crudely banded limy, garnetiferous, more or less silicified or silicated gangue. It trends northwestward, nearly along the strike of the limestone, and it dips steeply to the northeast, about conformably with the limestone, or stands about vertical. Its principal opening is a tunnel which, starting in the gulch, runs southwestward for about 30 feet, to a point where a 30-foot winze is sunk to the northeast. This winze contains some drift and gouging, and beyond the winze is a 9-foot chamber from which also considerable ore was probably taken out.

The opening as a whole shows the ore minerals to be principally the copper carbonates and the sulphides, chalcopyrite and bornite. They are contained in the vein or ore bed and also sporadically distributed and disseminated in the wall-rock limestone, particularly along the bedding and joint planes. In places they deeply penetrate the limestone itself, which is locally more or less garnetiferous, silicified or silicated, and seems to contain as much ore as the vein. A near-by cut shows similar though more finely banded or parallel streaked and veined occurrences of the ore in the silicified limestone.

TOANO GROUP.[1]

The Toano group, also called the O'Connell mine, from the name of the owner, is located on the granodiorite-limestone contact zone to the northwest of Toano John Peak, about 2 miles west of Trout Creek, at an elevation of about 6,400 feet. The topography is rough but not rugged. A wagon road leads up Trout Creek to the property.

The country rock is principally the light-colored limestone. It dips northward, away from the contact. The deposits are on the north or sedimentary side of the contact and occur chiefly in a parallel east-west ridge of the limestone. They are contained in four veins or lodes which, as shown on Plate XIV (p. 100), strike northwestward, approximately parallel with one another, and dip steeply to the northeast, into the mountain. These veins seem to represent replacements of porphyry dikes, which are more or less completely altered, replaced, and mineralized in the vicinity of the workings, but which plainly show their true porphyry-dike character in the limestone to the northwest and in the granodiorite to the southeast. Beginning on the west, No. 1 is a good 4-foot vein containing copper ore; No. 2, the most important of the group, is a lode 75 feet wide, composed principally of 40 per cent siliceous iron ore and containing at about the middle, as shown in the crosscut tunnel, a 20-inch vein that consists principally of copper oxide and carbonates averaging about 7 per cent in copper; Nos. 3 and 4, which have received but little exploitation, have a siliceous or quartz gangue.

---

[1] The information here given on this group, which was seen only from the region west of Trout Creek, was obtained chiefly from Mr. W. T. McArdle.

THE ELK MOUNTAIN DISTRICT.

GEOGRAPHY.

LOCATION.

The Elk Mountain district comprises a small area a few miles south of the Idaho State line. As shown on Plate I (p. 10), it is about midway between the northern boundaries of the Jarbidge and Contact districts, from each of which it is distant about 10 miles. It is about 25 miles southwest of Rogerson, Idaho, the nearest railway station on the Oregon Short Line. The nearest post office is Three Creek, Idaho, 9 miles distant on the northwest. With both of these places there are good wagon road connections. By trail the district is 30 miles from Contact and about the same distance from Jarbidge. From Contact, however, a wagon road extends to the Helsley ranch, a good stopping place within 8 miles of the district on the southeast.

TOPOGRAPHY.

The long, gently sloping, lava-covered ridge already described as extending from the Jarbidge district northeastward to the dam on Salmon River, near the middle part of its course, near the point where it crosses the State line at the 115° meridian, culminates in an elliptical group of mountains or elongated dome-shaped mass studded with low peaks that trend northeast and southwest for about 7 miles, with a maximum height of about 8,500 feet southwest of the State line. From the rounded, unit-like appearance of the mass on the north, the group is locally known as Elk Mountain, but from its dissected and composite character on the south it is more frequently called the Elk Mountains. According to J. F. O'Byrne, the State line crosses the northeast shoulder of the group.

On the southeast the mountains meet the surrounding lava plateau or plain of the Salmon River valley at an elevation of about 6,700 feet, above which their summit rises 1,800 feet. The mountains as a whole probably represent up-doming by a granodiorite stock, batholith or laccolith, similar to that in the Contact district. The granodiorite is exposed only in the southwestern part of the mountains, where they are most deeply dissected.

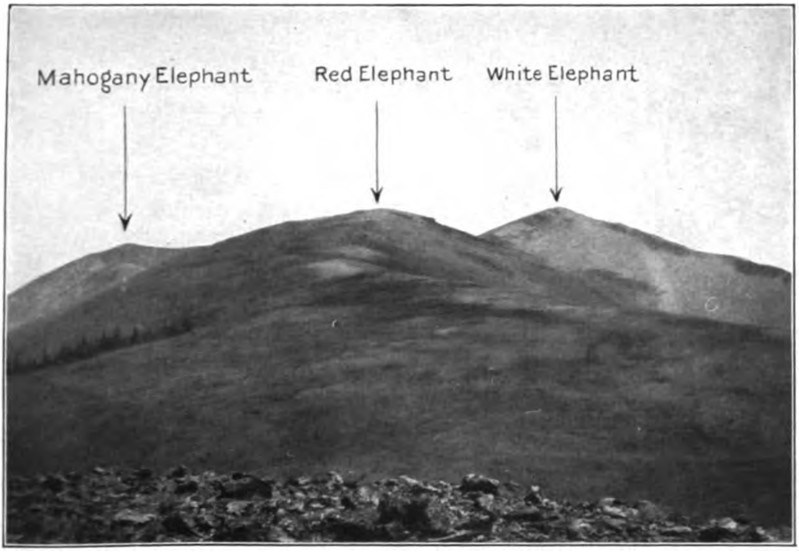
The Elk Mountain district here described is located at the southwest end of the group, on the headwaters of Salmon River, on the upper south slope of the divide that separates these waters on the southeast from the drainage of the East Fork of Bruneau River on the northwest, between elevations of 7,000 and 8,000 feet. The topography is mountainous and rough (Pl. XXVI), being of the same type as that of the Contact district, and is produced by deep erosion in the folded Paleozoic sedimentary rocks, which have been uplifted and tilted by plutonic masses covered by lava and subsequently denuded. The topography is mostly of the ridge and gulch type and trends south-southeasterly, at right angles to the axis of the mountains. The district is drained chiefly by Fall, Lime, and Willow creeks, small streams that flow eastward into Wilson Creek, which joins Salmon River below the Helsley ranch. Pole Creek, a larger stream, flows near by on the southwest.

GEOLOGY.

Geologically and mineralogically the Elk Mountain district, as indicated on Plate I (p. 10), is a replica of the Contact district, already described. It consists of a central intrusive granodiorite core, surrounded by a zone of Paleozoic sedimentary rocks, and an outer field of Tertiary lavas underlying the surface of the surrounding plateau.

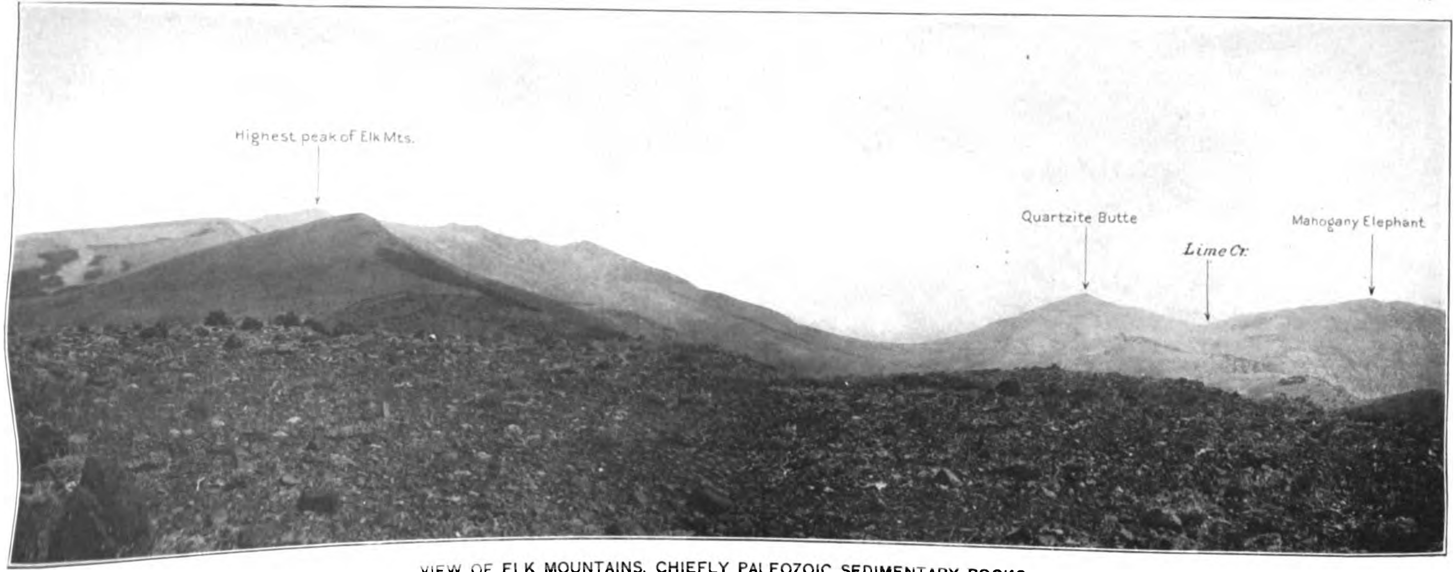
It lies in the Nevada Plateau, which is underlain by the Tertiary lavas and lake beds resting upon the folded and eroded Paleozoic sedimentary rocks. The Paleozoic rocks seem to consist of the same formations that appear in the Contact district, namely, limestone, quartzite, shale, slate, etc. They have been similarly domed up by a stock or mass of intrusive granodiorite, which apparently so shattered the beds in the crown of the dome that it soon became the seat of active erosion, which stripped back the quaquaversally dipping beds down the sides of the dome to the points where their upturned truncated edges now form a rim overlooking the still more deeply eroded granodiorite of the central area. The dip, which is fairly uniform, varies from 40° to 70°, the maximum observed being on the north. On the east it is about 50°, with decrease toward the south end. On the southeast the rim has been removed by erosion, which seems to be also the cause of the elongation of the central granodiorite area to a length of 1½ miles, against three-fourths of a mile in width.

The granodiorite is similar to that of the Contact batholith, except that it seems on the average to contain more bisilicates, notably hornblende, as at the Johnson mine. It consists essentially of plagioclase, orthoclase, quartz, hornblende, and biotite, with the accessories titanite or sphene, magnetite, and apatite. In the slide examined, which was obtained not far from the contact, calcite, pyrite, and much garnet are also present. The plagioclase seems to be oligoclase, about the same as that in the Contact batholith, but



A. EAST PRONG OF ELK MOUNTAIN MINERAL-BEARING HORSESHOE, LOOKING SOUTHEAST.

B. MAMMOTH VEIN IN CUT AND ORE, LOOKING NORTH.



VIEW OF ELK MOUNTAINS, CHIEFLY PALEOZOIC SEDIMENTARY ROCKS.

Left half is looking along crest of range, which extends 7 miles north-northeast to the Idaho State line.

owing to its altered condition the determination was not wholly satisfactory. The rock is regarded as of the same age (Cretaceous or near Cretaceous) as the Contact batholith. It is deeply oxidized, with the hornblende and feldspars much altered and sericitized, and, like the Contact rock, it is intruded by quartz syenite and quartz monzonite dikes, of which a dike of the aplitic phase occurs in the northwest slope of White Elephant Mountain.

The limestone in association with the deposits is chiefly the whitish or light-gray, finely crystalline, closely banded or straticulate rock, well shown in the west spur of Red Elephant Mountain along the road between the Austeon camp and tunnels.

About the middle of the east side of the granodiorite area is a low peak of white limestone known as the White Elephant, which reaches an elevation of about 8,070 feet, and of which the upper part is shown at the right in Plate XXV, *A*. About one-third of a mile to the northwest is a similar but less prominent swell known as Red Elephant Mountain, shown in the center of the same plate. Half a mile east of Red Elephant and separated from it by a narrow valley or gulch nearly 1,000 feet deep is a prominent outlying parallel short ridge or peak, shown at the left in Plate XXV, *A*, and at the right in Plate XXVI, which from its color and the scrub trees upon it is known as Mahogany Elephant. It seems to consist mostly of dark slate-colored thin-bedded blue limestone, slate, and shale, which dip outward (east) at angles of about 40°. In a similar but longer and larger mountain mass about a mile farther east, beyond Lime Creek, whose valley here seems to occupy a syncline, the dip is at about the same angle in the opposite direction, or west. In a similarly prominent mountainous outlier known from the rocks composing it as Quartzite Butte, which culminates in a sharp-crested ridge or peak (Pl. XXVI, at right of center), about a mile to the north of the one last described, the beds seem to dip 40° NW. toward the axis of the mountains.

If the dip of the rocks continues the same in the intervening valley as in Red Elephant and Mahogany Elephant, which seems probable, these two mountains, including the valley, expose a section about 1,300 feet in thickness; and in case the quartzite of Quartzite Butte, on the trend of whose strike the section is located, occurs at the base of the section, as seems likely, the total thickness of the Paleozoic rocks must be considerably greater than 1,300 feet, probably 1,600 feet or more.

On the west side of the area, which lies largely in the Fall Creek valley, the geologic section seems to be in descending order as follows: Rhyolite; light-colored limestone, 600 feet; quartzite (?), 300 feet; granodiorite.

The lava encircling the limestone zone and underlying the plateau on the outer side seems to be the young rim-rock lava of the Jarbidge district, with which it is apparently continuous, though in places débris or small exposures of rock resembling the old rhyolite of the Jarbidge district were also observed. It does not appear to exceed a few hundred feet in maximum thickness. It caps in scarp fashion the limestone to the west of the district, and with gentle dip it laps upon the west and northwest slopes of the mountains, reaching for the most part to the crest. Commencing at their north base it underlies the expansive plain, declining in long, gentle slopes toward Snake River on the north, as described in the section on the Jarbidge district. At a mile or more to the northwest of the Elk Mountain district the piedmont tributary valley of the East Fork of Bruneau River, several hundred feet deep, is seemingly cut through the lava into the underlying limestone. From the base of the mountains and limits of the Paleozoic rocks on the southeast the lava underlies a benched valley plain or mesa, several miles in width, which slopes southward or downstream, with the valley of North Salmon River, and seems to be continuous with the similar lava mesa in the southwestern part of the Contact district. From the base of the mountains the lava also inclines at a low angle laterally toward the river and the Helsley ranch, near which it breaks off abruptly in steep scarps or bluffs 100 feet or more in height overlooking the younger portion of the valley now occupied by the river. As a result of these conditions the tributary streams, which near the mountains flow almost upon the surface of the plain, emerge at the foot of the scarp through narrow, deeply cut notches or passes, affording in most places the only means of access to the plains from the valley side.

MINERAL DEPOSITS.

GENERAL FEATURES.

Mineral was known in the Elk Mountain district at least as early as 1890, since which date W. H. Austeon, a pioneer of Silver City, Idaho, as well as of this district, has annually carried on work here. His cabin and buildings, located in the northwestern part of the district at an elevation of about 7,600 feet on the head of Fall Creek, seem to be about the only permanent camp. The district, however, as a whole is still in the prospect stage, its most extensive openings not exceeding 200 feet in depth. At present ground is held and assessment work is being done on it by a dozen or more persons.

As in the Contact district, the deposits occur principally in association with the contact zone of the intrusive granodiorite and the Paleozoic limestone and are regarded as of Cretaceous or near Cretaceous age. They seem to be mostly of the contact-metamorphic type, with more or less massive garnetiferous chloropal and siliceous ferruginous matter in the gangue.

The metal of the district is chiefly copper, with which, however, is associated also gold and silver. A tin can placed in the creek at the foot of the mountains, it is said, soon becomes copper plated. The gangue here is not so ferruginous as in the Contact district, nor is the garnet so massive. Some of it shows well-developed crystal forms of garnet. The minerals observed in association with the deposits are as follows:

Aragonite.
Argentite (?).
Axinite (?)
Calcite.
Chert.
Chloropal.
Flint.
Garnet.
Gold.
Hematite.
Limonite.
Manganese.
Molybdenite (?).
Pyrite.
Quartz.
Silver (?).
Stibnite.

The ore minerals are malachite, azurite, chalcopyrite, bornite, chrysocolla, gold, and silver.

The deposits are mostly on the arms of a horseshoe-shaped belt along the east and west sides of the granodiorite area, the toe portion on the north being apparently more deeply buried or less favorable for the occurrence of mineral and its exploitation.

The outcrops or "copper cap rock" as shown on the Austeon property, on the west spur ridge of Red Elephant Mountain near the west arm of the horseshoe, seems to consist mainly of reddish-brown, greenish, and blackish iron, copper, and manganese stained, altered, and in part mineralized granodiorite and limestone. Locally they are seemingly brecciated and here and there they constitute fair-grade ore.

AUSTEON TUNNELS PROSPECT.

A little farther down the slope from the outcrops just referred to, the Austeon tunnels ground is opened principally by a 130-foot tunnel and a 200-foot tunnel, spaced about 200 feet apart vertically, and both driven northward in the granodiorite to strike the Austeon 6-foot transverse vein, which is said to average about 3 per cent in copper and $7 in gold to the ton and to contain some beads or small nuggets of native copper. The granodiorite is mostly altered and barren or only slightly mineralized. At about 190 feet in from the portal of the lower tunnel, however, which is at an elevation of about 7,150 feet, firm, hard granodiorite is encountered, which is darker, with more green hornblende, than the average of this rock and contains also pyrite and calcite.

O'NEIL PROSPECT.

Near the south end of the west arm of the horseshoe is the O'Neil property, owned by O'Neil Bros. It seems to be one of the best showings in the district, and is said to be located on a good-looking persistent ledge, much of which carries about 16 per cent of copper.

RED ELEPHANT INCLINE.

The Red Elephant incline is located on ground owned by W. H. Austeon at the east contact, on the upper southwest slope of Red Elephant Mountain, at an elevation of about 8,180 feet. Following the granodiorite contact, which dips 30° to 40°, it extends N 30° E. for 155 feet in massive white fine to medium grained crystalline limestone and exposes the following section, which seems not only to be coextensive with the incline, but to continue beyond it in depth.

Section in Red Elephant incline.

	Feet.
Crushed and partly silicated and mineralized brownish and mottled limestone, containing flint or chert and manganese oxide and running from 1 to 2 per cent of copper, mostly in malachite, oxide, and chrysocolla	8
Garnetiferous, finely banded reddish, brownish, greenish, and bluish mottled altered limestone and garnetiferous chloropal gangue with malachite, azurite, chalcopyrite, and bornite, averaging as a whole about 3 per cent in copper and small values in gold and silver	6½
Bedrock granodiorite.	

There seems to be here a 14½-foot bed or body of low-grade ore which, if it continues in extent and depth, as appears to be the case, will probably be some day profitably worked.

GOLD PROSPECT.

A few hundred yards southeasterly of the incline opening just described and somewhat higher up the slope, on the same Austeon ground and in the same limestone country rock, occurs a parallel 2-foot impure quartz ledge or bed said to carry fair values in antimonial gold. The ledge, which is opened by a small pit or cut and shows portions resembling breccia, seems to be a replacement in the limestone along a fault plane. The outcrops are mostly reddish and dark-brown iron-stained siliceous material. The antimony is present as stibnite in the massive form, in impure dark-gray or blackish submetallic-looking small sheets or veinlets, films, and irregular bodies. Associated with the deposit is also considerable iron oxide and some yellowish material, apparently lead, and dark argentite.

ESTES PROSPECT.

The Estes prospect lies on the upper northerly slope of White Elephant Mountain, at an elevation of about 8,050 feet, on the contact between silicified garnetiferous limestone and granodiorite, with well-developed crystalline garnet in the gangue. The principal deposit consists of a bed 1 foot wide containing numerous pockets of good-grade copper ore.

OTHER PROSPECTS.

At the south end of the east contact, at the base of White Elephant Mountain, is the Robinette prospect, said to present a good showing. On the northeast or outer side of the contact zone are also a number of outlying prospects in the limestone and quartzite, which were not visited in the course of this investigation.

INDEX.

A. Page.
Acknowledgments to those aiding.......... 9–10
Adularia, character and distribution of....... 52–57
  from Silver City, analysis of.......... 53
    alkalies in.......... 53
  replacing calcite, plates showing.......... 54, 56
Allen and Delano claims, development of..... 119
Alluvial deposits, of Jarbidge district, character of.......... 33
Amazon-Rainbow group, development of..... 88
Antelope mine, development of.......... 122–123
Arkansas property, character of vein on...... 92–93
Austeon Tunnels prospect, development and deposits of.......... 155

B.
Basic dikes, of Contact district, character and distribution of.......... 111–112
Bear Creek, description of.......... 26
  mining development near.......... 97
Big Crater, mining development in.......... 89–92
Big Ledge group, development of.......... 95–96
Black Jack mine, Silver City, Idaho, adularia from, analysis of.......... 53
Blake group (Mahogany mine), deposits and development of.......... 87
Blanchard Mountain area, mining development in.......... 139–146
Blue Bird mine, development and ore deposits of.......... 121
Blue Rock group, deposits of.......... 132
Bluster mine, development and production of. 80–82
Bonanza mine, development and deposits of.......... 126–129
Bonanza mine and camp, plate showing..... 126
Boston mine, development of.......... 149–150
Bourne mine, geology, ore, developments, and production of.......... 73–76
  ore from, analysis of.......... 53
Brooklyn mine, discovery, development, and ore deposits of.......... 117–119
  plate showing.......... 118
Bruneau River, description of.......... 27
Buck Creek, placer deposits of.......... 98
Buster Brown claim (Guess property), development and ore of.......... 86
Buster mine, development of.......... 76–77
Buster vein outcroppings, plate showing..... 50

C.
Camp Bird property, development of......... 95
Camp Bird prospect, deposits of.......... 138–139
Chinaman mine, deposits and development of.......... 136–137
  section at.......... 136
China Mountain area, mining development in.......... 134–139
Clark group, deposits of.......... 147–149
Climate, of Contact district, character of.... 101–102
  of Jarbidge district, description of........ 13–14
Cœur d'Alene-Jarbidge property, development of.......... 92
Comet property, development of.......... 95
Contact, plate showing.......... 102
Contact district, general geology and mineral deposits of.......... 99–150
  geologic map and sections of.......... 100
  history and present conditions of....... 102–104
  location of, maps showing.......... 10, 12
  location of claims in, map showing....... 112
  mineral deposits of.......... 112–117
  mines of, detailed descriptions of....... 117–150
  precipitation and temperature of....... 101–102
  topography and drainage of.......... 99–101
  vegetation of.......... 102
  veins, dikes, and deposits in, map showing.......... 112
Contact-metamorphic deposits, of Contact district, character and distribution of.......... 114–115
Coon Creek, mining development near....... 97
Copper King claim, development of........ 121–122
Copper Shield and neighboring groups, deposits of.......... 132–133
Crater Range, topography of.......... 24–25
Cross system, of Jarbidge district, mineral deposits of.......... 52
Curley lease, development and production of. 71–72

D.
Deer Creek, description of.......... 26
  mining development near.......... 97
Delano claims, development of........ 119, 121–122
Dike rocks, of Contact district, character and distribution of.......... 109–112
Drainage, of Contact district, outline of..... 99–101
  of Jarbidge district, outline of.......... 24–27
Duffy claim, development of.......... 72

E.
East Fork, description of.......... 26–27
  mining development along.......... 96
East system, of Jarbidge district, mineral deposits of.......... 51
  of Jarbidge district, mining properties on. 66–88
Effie Fay group, deposits of.......... 132
Elk Mountain, east prong of, plate showing... 152
  view of, plate showing.......... 152

Page.
Elk Mountain district, geology and mineral deposits of.................... 151-157
  geography of.......................... 151-152
  location of, maps showing............... 10, 12
  mines and prospects, descriptions of... 155-157
Ellen D. Mountain area, mines and prospects of............................ 117-134
Emmons, S. F., on rhyolite................ 20
Emmons, W. H., on Tertiary volcanic rocks......................... 31-32, 35
Empire mine, development of............... 119
Eocene rocks, of Jarbidge district, character and distribution of.............. 31
Estes prospect, deposits of................... 157
Eureka region, geologic section in............ 30-31

F.

Fifth Crater, mining properties in........... 94
First Crater, mining development in......... 94-95
  part of rim of, plate showing............. 24
Fissure-vein deposits, of Contact district, character and distribution of.. 115-116
Florence group, deposits of................. 132-133
4-M lease, development and production of... 68-69
Fourth Crater, mining development in...... 93-94
Fox Creek, description of.................... 25
Free Gold group, location of................. 83
Freighting, to Jarbidge district, cost of...... 17

G.

Geologic history of Contact district, summary of.............................. 112
Geology, of Contact district, description of.. 104-112
  of Elk Mountain district, description of. 152-154
  of Jarbidge district, description of........ 27-47
Glacial deposits, of Jarbidge district, description of.......................... 32
Gold, in Jarbidge district, early discoveries of.............................. 15
  in Jarbidge district, occurrence and values of........................ 57-58
Golden Eagle claim, deposits and development of......................... 87
Golden Queen claim, deposits and development of......................... 87
Gold ore, "blistery" and nodular phases, plate showing................... 62
  photomicrograph of..................... 60
Gold prospect, deposits of.................. 156
Good Luck property, development and ore of 82-83
Granodiorite, from Shoshone Peak, analysis of.............................. 34
  weathering of, in the Contact district, plate showing.................. 102
Great Basin province, physical features of... 19
Guess property, development and ore of..... 86

H.

Ham-and lease, development and production of.............................. 71-72
Hematite, occurrence of, in gangue of Jarbidge district..................... 56
Hice mine, development of................ 143-145
Hickey prospect, deposits of................. 134
High Ore mine, development of............. 138
Horseshoe Crater, mining development in.... 89-92
Howard-McCoy mine, plate showing......... 24
  vein structure of........................ 91-92
Humboldt formation, character and distribution of.......................... 32

I.

Igneous rocks, of Contact district, character and distribution of............ 107-112
  of Jarbidge district, character, age, and distribution of................. 33-47
Intrusive granitic rocks, of Contact district, character and distribution of... 107-108
It claim, vein at.......................... 82
Ivy Wilson group, development and deposits of.............................. 129-132

J.

Jack Creek, description of.................. 26
Jack Creek area, mining development in..... 95-96
Jack Crater, mining development in......... 94-95
Jarbidge, plate showing................... 16
Jarbidge district, geology and mineral deposits of....................... 11-98
  geology of, general features of............ 27-47
    sections and maps showing.......... 10, 12
  history of............................... 14-19
  location of.............................. 11-13
    maps showing....................... 10, 12
  maps showing claims in.................. 66
  mineral deposits of, character and distribution of....................... 47-66
  mining properties of, detailed descriptions of......................... 66-98
  name of, derivation of................... 11
  physical features of...................... 19-27
  precipitation and temperature of......... 13-14
  present conditions in.................... 14-19
  previous descriptions of................. 13
  vegetation of........................... 14
  veins in, trend and position of, figure showing......................... 49
Jarbidge Mountains, physical features of..... 21-27
Jarbidge River, description of............... 25-26
  old rhyolite near, plate showing......... 24
  placer deposits of...................... 97-98
Johnson group, development of............ 141-142
Josephine group, development at............ 82

K.

King, Clarence, on age of Nevada rhyolites... 46
Knoll Creek valley, lake beds in, plate showing.............................. 100
Kratz mine, development of............... 145-146

L.

Lamphrophyric dikes, of Contact district, character and distribution of... 111-112
Lavas, of Jarbidge Mountains, character and distribution of.................. 22-27
Lindgren, Waldemar, on dike rocks......... 109
  on values of gold veins in depth......... 64
Lumber, in Jarbidge district, cost of......... 17

M.

Mahogany mine, deposits and development of.............................. 87

Page.

Mammoth and neighboring prospects, deposits of 124-126
Mammoth claim, ore deposits of 86
Mammoth vein and ore, plate showing 152
Marys River, mining development near 96-97
Middle Stack Mountain, plate showing 100
Middle Stack Mountain area, mining development in 146-150
Mineral deposits, of Contact district, character, distribution, and subdivisions of 112-117
  of Jarbidge district, character and distribution of 47-66
Mines and prospects, of Contact district, detailed descriptions of 117-150
Missmo group, development of 76

N.

New York vein outcroppings, plate showing. 126

O.

O'Connell group, deposits of 146-147
Old Contact, plate showing 102
Old rhyolites, of Jarbidge district, character and distribution of 36-42
  of Jarbidge district, composition and analyses of 40-42
    macroscopic character of 38-39
    microscopic character of 39-40
    plates showing 16, 24
    structure of 37-38
O'Neill prospect, deposits of 156
Ozark group, geology and ore deposits of 84-86

P.

Paleozoic rocks, of Contact district, character and distribution of 104-107
  of Contact district, section of 105
  of Jarbidge district, character and distribution of 27-31
Palo Alto mine, development of 120
  plate showing 100
Pan mine, development and production of... 72
Pavlak lease, development and production of 70-71
Pavlak mine, geology, ore, developments, and production of 67-68
  occurrence of gold at 57
Pick and Shovel mine, ore and developments of 77-79
Pick and Shovel mine and vein outcroppings, plate showing 50
Pickett, R. D., work of 9
Pine Creek, description of 25
  mining development near 97
Pine Creek valley, plate showing 24
Placer deposits, distribution and character of 97-98
Pliocene rocks, of Jarbidge district, character and distribution of 31-32
Pseudomorphic quartz after calcite, plates showing 54, 56

Q.

Quartz-adularia gangue, of Jarbidge district, character and distribution of 52-57
Quaternary deposits, of Jarbidge district, description of 32-33
Queen of the Hills prospect, deposits of 123-124

R. Page.

Railway facilities, of Contact district, discussion of 103
  of Jarbidge district, discussion of 11
Rattler prospect, deposits of 124
Red Bird claim, development of 72
Red Elephant incline, deposits and section of. 156
Replacement deposits of Contact district, character and distribution of... 116-117
Rhyolites, plates showing 16, 24
  See also Old rhyolites; Young rhyolites.
Riddle lease, development and production of. 69-70
Roads in Jarbidge mining district, condition of 17-18
R. O. C. prospect, development of 142-143
Rock Creek Fraction claim, vein at 82
Round Up group, development of 94

S.

St. Joe group, location and development of.. 83
Salmon River, description of 100-101
  mining development near 96-97
Salt Lake group, deposits of 132, 133
Scott, W. A., on water-supply of Jarbidge River 26
Second Crater, mines in, plate showing 24
  mining development in 89-92
Sedimentary rocks of Contact mining district, character and distribution of... 104-107
  of Jarbidge district, character and distribution of 27-33
Sericite, occurrence of, in gangue of Jarbidge district 55
Shoshone Peak, analysis of granodiorite from. 34
Siliceous dikes of Contact district, character and distribution of 110-111
Snake River canyon, geologic section in 20
Snake River province, physical features of.. 19-21
Snowslide deposits, of Jarbidge district, description of 32
Snowslide Gulch, development work on 93
South Branch valley, plate showing 16
Success group, value of ore from 82
Sugar group, development of 94
Sunflower group, development of 72
Sweetser, N. W., on Paleozoic sedimentary rocks 26
  work of 9
Syenite dike, plate showing 118
Syenite dikes of Contact district, character and distribution of 110-111

T.

Tacoma group, deposits and development of. 87
Talus deposits of Jarbidge district, character and distribution of 33
Tertiary lake beds of Contact district, character of 106-107
Tertiary rocks of Jarbidge district, description of 31-32
Tertiary volcanic rocks of Contact district, character and distribution of... 108-109
  of Jarbidge district, general features of... 35
Third Crater, mining development in 92-93
Thompson Gulch, plate showing 109
Toano group, deposits of 150

Page.
Trout Creek area, mining development in.. 146-153
True Fissure group, development of......... 99
Turo mine, development of.................. 138
Turo-Sheckles mine, development and deposits of........................ 137-138

V.

Van Alder mine, normal fault structure in, figure showing.................... 90
  vein structure and ore deposits of........ 89-91
    plate showing........................ 24
Vegetation in Contact district, character of.. 102
  in Jarbidge district, character of......... 14
Veins of Jarbidge district, origin of.......... 58-64
  of Jarbidge district, structure and composition of......................... 52-57
Victoria group, development of.............. 92
Volcanic rocks, of Jarbidge district, age of.... 46-47
Vulcan group, location of.................... 87

W.

Wall rock, alteration of...................... 64-66
Wall Street group, development of........... 94
War Eagle mine, development and deposits of.............................. 136-137
Water power, availability of, for Contact district.............................. 104
  availability of, for Jarbidge district...... 18
West system, of Jarbidge district, mineral deposits of....................... 50-51
  of Jarbidge district, mining properties on. 66-88
White Quartz vein, character of............. 94
Winkler mine, development and production of................................ 80-82

Y.

Yellow Girl mine, development of........... 134
Young rhyolites, of the Jarbidge district, character and distribution of..... 42-46
  of the Jarbidge district, macroscopic character of.......................... 44
    microscopic character of............. 44-46

Z.

Zetta Blanchard group, deposits and development of.................... 140-141
Zirkel, F., on tridymite...................... 45

○

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 498

HEADWATER REGIONS OF GULKANA AND SUSITNA RIVERS ALASKA

WITH ACCOUNTS OF THE VALDEZ CREEK AND CHISTOCHINA PLACER DISTRICTS

BY

FRED H. MOFFIT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

CONTENTS.

Page.
Preface, by Alfred H. Brooks 7
Introduction 9
Geography 11
  Location and area 11
  Topography 12
    Relief 12
    Drainage 13
  Climate 15
  Vegetation 16
  Population 18
  Trails and transportation 19
General geology 21
  Stratigraphy 21
    Introduction 21
      Gulkana and Susitna river region 21
      Chistochina district 23
    Pre-Ordovician (?) rocks 24
      Birch Creek schist 24
      Age 26
    Probable pre-Carboniferous sedimentary rocks 26
      Distribution and character 26
      Age 26
    Carboniferous rocks 27
      Sedimentary deposits 27
        Character and distribution 27
        Age and correlation 28
      Basic lavas and tuffs 29
        Character and distribution 29
        Age 29
    Triassic rocks 31
      Character and distribution 31
      Age and correlation 33
    Jurassic (?) rocks 33
      Character and distribution 33
      Age of the diorite intrusives 35
    Tertiary rocks 35
      Character and distribution 35
      Age and correlation 38
    Quaternary deposits 39
      Deposition 39
      Glacial deposits 39
      Stream and lake gravels 41
    Structure 45

Page.
Historical geology 47
  Early geologic history 47
  Later geologic history 49
    Topographic development 49
    Glaciation 51
Economic geology 53
  Gold 53
    Valdez Creek district 53
      History and production 53
      Source of the gold 55
      Lode deposits 56
      Placer deposits 57
        Distribution 57
        Valdez Creek proper 57
        Lucky Gulch 63
        White and Rusty creeks 64
        Timberline Creek 65
    Delta River district 65
    Conditions affecting mining 66
    Suggestions 68
  Coal 69
Chistochina district 70
  Introduction 70
  Geography and drainage 70
  History 71
  Trails 71
  Mail and telegraph facilities 72
  Gold placers 72
    Output 72
    Detailed descriptions 72
      Miller Gulch 72
      Slate Creek 73
      Big Four claims 74
      Ruby Creek 75
      Chisna River 75
      Lime Creek 78
    Origin of the gold 78
      Influence of glaciation 79
  Economic conditions 79
Index 81

ILLUSTRATIONS.

Page.
PLATE I. Topographic reconnaissance map of the region between the headwaters of Susitna and Gulkana rivers ____ In pocket.
II. Geologic reconnaissance map of the region between the headwaters of Susitna and Gulkana rivers ____ In pocket.
III. Geologic reconnaissance map of a part of the central Copper River region ____ In pocket.
IV. *A*, Landslide on northern tributary of Eureka Creek; *B*, Conglomerate associated with Triassic sediments between Roosevelt Lakes and Big Clearwater Creek ____ 32
V. *A*, Basalt Mountains on the south side of Windy Creek; *B*, Upper valleys of White and Big Rusty creeks ____ 40
VI. *A*, Rock glacier on Big Rusty Creek; *B*, "Soil flows" at the head of Valdez Creek ____ 44
VII. *A*, View across Gulkana Glacier from the west side, showing a type of Alaska Range topography; *B*, Topography of lower Valdez Creek from the north ____ 52
VIII. *A*, Bowlder deposits on Valdez Creek; *B*, Wing dam in canyon on creek claim adjoining the "Tammany bench," Valdez Creek ____ 58
IX. *A*, Tertiary conglomerate and sands on a tributary of Phelan Creek; *B*, The Monahan tunnel and second creek claim above Discovery on Valdez Creek ____ 60
X. *A*, Gold nuggets from Lucky Gulch; *B*, Boomer and dam on Rusty Creek ____ 62
FIGURE 1. Outline map of a part of southern Alaska, showing the area represented by Plates I and III ____ 11
2. Section of Pleistocene on Klawasi River ____ 42
3. Section of Pleistocene on Klutina River, 6 miles above Copper Center ____ 43
4. Section of Pleistocene on west bank of Copper River ____ 43
5. Structure of the Alaska Range in the vicinity of Chistochina River ____ 46
6. Structure of the Alaska Range in the vicinity of Delta River ____ 46
7. Relations of present and Eocene land surfaces in the Copper River valley ____ 50
8. Sketch map of part of Valdez Creek, showing location of producing claims ____ 59
9. Relations of the old canyon of the Tammany bench claim to the present channel of Valdez Creek ____ 61

PREFACE.

By Alfred H. Brooks.

Systematic geologic and topographic reconnaissance surveys of Alaska were begun in 1898 and have now (1911) been carried over about one-fifth of the Territory. The first few years were largely devoted to exploration, the areal surveys being limited to the regions adjacent to the routes of travel. Later, areal surveys were made of the more important mining districts, and by 1910 geologic and topographic reconnaissance maps had been completed of most of the districts that had made any considerable contribution to the annual mineral output of Alaska. In addition to this, detailed maps had been made of several of the best-developed mining camps, such as Juneau, Fairbanks, and Nome. This progress made it possible in 1910 to extend the surveys into new fields and thus to cover some of the less important mining districts.

As a result, the survey was undertaken of the area here described, which, prior to 1910, had been known only through the journeys of the indefatigable prospectors. One of the chief purposes of this survey was to map and investigate the Valdez Creek placer district, which has been producing gold for a number of years.

The geologists, F. H. Moffit and B. L. Johnson, and the topographers, D. C. Witherspoon and C. E. Giffin, results of whose surveys are here published, deserve great credit for the work accomplished. In a season comprising only 74 days the two topographers surveyed an area of 4,980 square miles and the two geologists mapped about 2,000 square miles besides making a somewhat detailed study of the Chistochina and Valdez Creek placers. The geology of the Chistochina region was investigated by W. C. Mendenhall in 1902, and the results of his investigations were published,[1] but as a part of that district lies in the same geologic province with Valdez Creek and was reexamined by the Moffit party it was decided to include a summary of Mendenhall's report in this volume.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1904.

Among the important geologic discoveries here set forth is the occurrence of Triassic sediments in this part of Alaska. They are locally metamorphosed by the great belt of intrusive rocks that bound them on the north. The auriferous gravels of Valdez Creek are derived from Triassic sediments, and those of the Chistochina region from Carboniferous sediments. In both districts the mineralization is genetically related to granitic intrusives, and, as in other parts of Alaska, the gold-bearing veins seem to occur chiefly outside the zone metamorphosed by the intrusives. Igneous intrusion is common in this province, and it seems probable that the conditions favorable to the occurrence of gold may be repeated elsewhere than in the districts in which placers have already been developed.

HEADWATER REGIONS OF GULKANA AND SUSITNA RIVERS, ALASKA, WITH ACCOUNTS OF THE VALDEZ CREEK AND CHISTOCHINA PLACER DISTRICTS.

By Fred H. Moffit.

INTRODUCTION.

The purpose of this paper is to describe the geology and mineral resources of an area between the upper parts of Susitna and Gulkana rivers. The work on which the description is based was wholly reconnaissance in character and was not sufficiently careful or extensive to permit accurate mapping of formation boundaries in many places nor to determine fully the structural and stratigraphic relationships between the various rock masses referred to here.

The lateness of the spring and the time consumed in traveling to and from the field of work at the beginning and the end of the summer reduced the time available for geologic work during the open season of 1910 to 59 days, of which a week was spent in visiting the Chistochina gold-placer district, leaving only 52 days for studying the region west of the Gulkana. The geologic work was part of a larger plan that included topographic as well as geologic mapping, with the object of extending westward the surveys begun by T. G. Gerdine and W. C. Mendenhall in the upper Copper River valley in 1902. This work, the first done by the United States Geological Survey in the headwater region of Susitna River, was undertaken primarily because of the importance of the Valdez Creek gold-placer district and the numerous requests that have been made for information about it.

The topographic mapping was in charge of D. C. Witherspoon, who was assisted by C. E. Giffin. Their surveys are embodied in the topographic map published with this report (Pl. I, in pocket) and form the base for the geologic map that accompanies it. The geologic map (Pl. II, in pocket) represents the work of B. L. Johnson and the writer. Mr. Johnson was associated with the writer in the field studies and prepared the office drawings of the geologic map. These maps, together with those surveyed by J. W. Bagley and S. R. Capps[1] in this same year (1910), give a complete section across the Alaska Range.

---

[1] Capps, S. R., The Bonnifield region: Bull. U. S. Geol. Survey No. 501, 1912.

Although the investigations were carried on in a district that had not been previously described, reference should be made to earlier work in adjacent districts both to the east and to the west. The earlier investigations were begun in 1898, when G. H. Eldridge[1] and Robert Muldrow, of the United States Geological Survey, ascended the Susitna to Indian Creek, where they left the main river and made their way north into the Alaska Range as far as Yanert Fork of Nenana River. Their trail along Jack River brought them to a point within 30 miles of the head of Susitna River and directly west of it. This trip was made under great difficulties, owing to unfavorable weather conditions, failure of supplies, and inexperience in Alaska work, but it yielded the only information yet secured concerning the geology of the district between Susitna River and the Nenana.

In the same year (1898) W. C. Mendenhall,[2] of the United States Geological Survey, who was attached to a military expedition under Capt. Glenn, crossed the Copper River lowlands from Matanuska River to Delta River and descended the latter stream to a point less than 10 miles from Tanana River. The route followed by this expedition was from Matanuska River, at Hicks Creek, in a general northeasternly direction past the east end of Lake Louise, one of the large Susitna lakes, to the Tangle Lakes. Two large branches of Gulkana River were crossed between Lake Louise and the Tangle Lakes and were supposed at that time to be the Gakona and Chistochina rivers represented on Lieut. Allen's map. From the Tangle Lakes country the route led down the east bank of Delta River as far as Jarvis Creek, at which point the greater part of the expedition turned back because of failing supplies.

The surveys of 1902 differed in character from the two exploratory expeditions just referred to. In that year T. G. Gerdine and W. C. Mendenhall[3] made a reconnoissance topographic and geologic map of a large area, including the central Copper River district and the south slope of the Alaska Range from Delta River to a point within a few miles of Mentasta Pass. Their work will be referred to later in this report.

Reports of minor scouting trips made to their superior officers by members of the two military expeditions in charge of Capts. Glenn and Abercrombie, in 1898, are contained in the reports of these two officers to the War Department.

---

[1] Eldridge, G. H., A reconnaissance in Susitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 7–29.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 271–340.

[3] Mendenhall, W. C., and Schrader, Frank C., The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903. Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905.

The writer wishes to express his appreciation of the kindness shown to himself and to members of his party by the miners of Valdez Creek. They are too many to mention individually, but he is particularly indebted to Mr. Peter Monahan, Mr. William Grogg, and Mr. Clark Duff for information about the history of mining on Valdez Creek and for many facts concerning its gold placers that he would not have obtained except for their interest in the work. The writer is also greatly indebted to Mr. B. L. Johnson for many suggestions and for much valuable aid in the preparation of this paper.

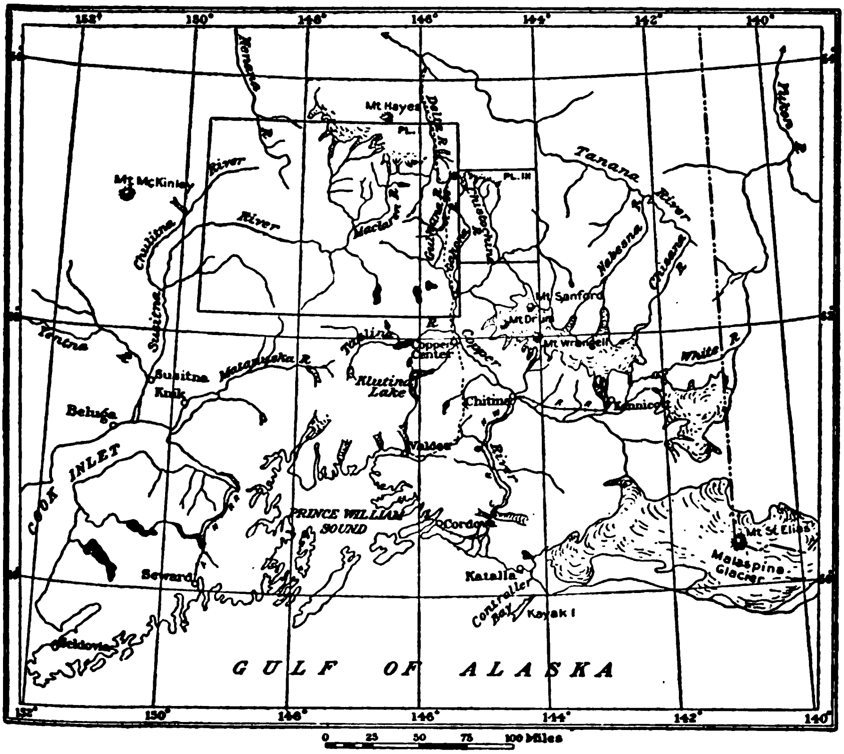


FIGURE 1.—Outline map of a part of southern Alaska, showing the area represented by Plates I and III (in pocket).

GEOGRAPHY.

LOCATION AND AREA.

The district under consideration lies south of the Alaska Range and includes parts of the drainage basins of Copper River, Susitna River, and Tanana River. It is included within meridians 145° 20′ and 147° 40′ west longitude and parallels 62° 20′ and 63° 40′ north latitude. Approximately 5,000 square miles of the quadrangle thus defined was surveyed in 1910 and is represented on the topographic map (Pl. I, in pocket). The location of this quadrangle is shown on the outline map of southern Alaska (fig. 1).

Gulkana, on the military road from Valdez to Fairbanks, is just within the southern boundary of the area mapped, and at the present time is the point of entry for the district. The mapped area extends from the latitude of Gulkana north to the summit of the Alaska Range. Gulkana River and Susitna River mark its eastern and its western limits.

TOPOGRAPHY.

RELIEF.

The topographic map represents a district whose northern border is made up of high, rugged mountains (Pl. VII, *A*, p. 52), most of which are well above snow line, and consequently form a gathering place for snows and ice that supply scores of glaciers and give rise to hundreds of streams. The axis of the Alaska Range, within the limits of the map, runs west-northwest from the mountains at the head of Gulkana Glacier through Mount Hayes to Cathedral Mountain, near the western border of the map, where it swings to the west, and finally to the southwest, beyond Nenana River, toward Mount McKinley.

South of the high, snowy mountains that here form the backbone of the Alaska Range is a parallel range, scarcely separated from the main range west of Maclaren River, but entirely distinct to the east. The mountains composing this parallel range are also rugged, but their peaks are not so high as those on the north, and the snow fields and glaciers are absent or are too small to be considered. Like the main range on the north, the trend of these mountains changes from west-northwest to west from Delta River and becomes southwest beyond Susitna River. Still farther south is a third parallel ridge with an east-west trend, made up of low rounded hills. This ridge is separated from the higher one on the north by a broad depression and merges on the south into the lake-dotted flats of the Copper River lowland. Thus, within a distance of 50 miles from north to south, the remarkably rugged topographic forms of the snow-covered Alaska Range change to the monotonous level of the great interior basin of Copper River and the upper Susitna.

The difference in relief between the highest and the lowest points within the district is approximately 12,000 feet; Gulkana is 1,300 feet above the sea; and Mount Hayes, the highest peak in this part of the Alaska Range, is almost 14,000 feet above sea level. Susitna River, at the mouth of the Maclaren, is approximately 2,400 feet above the sea. In a very general way it may be said that the elevation of the main part of the Alaska Range from Delta River to Mount Hayes ranges from 7,000 to nearly 14,000 feet above sea level; the average elevation of the next range to the south is about 6,000 feet; and that of the third and lowest range about 5,000 feet above sea level, or only 3,000 feet above the lowlands of the Copper and the Susitna. Such figures, of course, are not intended to be accurate, but they serve to give a better idea of the relief of the region than would be gained without careful study of the topographic map.

The topography of the northern half of the mapped area everywhere gives evidence of the effects of intense and recent glacial activity. This is shown most plainly in the rugged mountain areas by the forms of the valleys and in the more open country flanking the mountains by morainic deposits. Farther south the evidences of glaciation are not so marked, but the broad gravel plains with their hundreds of lakelets and their acres of marshy ground are doubtless closely connected in origin with the invasion and retreat of the ice.

Topographic forms in the southern half of the mapped area present a marked contrast to those of the northern half. The hills and mountains rise from a basement lowland where flat or rolling country predominates. A few prominent isolated mountains, like the one north of the lower part of Maclaren River, together with the ridge south of it, appear to belong to an older topography than the high country to the north. Angular outlines have been replaced by smooth, rounded contours, and in many places flat-topped and terraced hills are prominent features of the sky line.

The lowland area possesses little relief. Low gravel ridges are scattered over it and the streams have intrenched themselves in its surface, but these features are so slight as to attract little attention when seen from the bordering hills. From the vicinity of Lake Louise the lowland slopes gently toward Susitna River on the west and toward Copper River on the east. Copper River and the lower parts of its tributary streams have incised their channels several hundred feet below the general surface. Susitna River, on the other hand, in that part of its course represented on the map, has not been able to depress its channel much below the level of the adjacent gravel plains and shows no such gravel bluffs as those present along Copper River. The central part of the lowland seems as yet scarcely to have been affected by stream erosion.

DRAINAGE.

The district extending west from Gulkana River to Susitna River on the south side of the Alaska Range belongs to three main drainage systems—those of Copper, Susitna, and Tanana rivers. The eastern half of the district is drained by Delta and Gulkana rivers and the western half by Susitna and Nenana rivers and their tributaries. Both Delta River and Nenana River belong to the Tanana drainage basin, for although they originate on the south side of the Alaska Range, they cut through it and flow into Tanana River. Delta River drains approximately one-fifth of the eastern half of the district;

Nenana River only a few square miles in the northwest corner of the western half. Most of the Susitna drainage is from the glaciers and snow fields of the high mountains; most of the Gulkana drainage is from the lowlands; but that of the Delta is derived in about equal amounts from the glacier waters of Eureka and Phelan creeks and the clear-water streams of the intermediate range and the Tangle Lakes region.

Gulkana River heads in Gulkana Glacier, but receives most of its water from two branches that rise in the lake country on the west. It is a clear-water stream below Gulkana Lake, because Summit Lake and Gulkana Lake act as settling tanks for the silt-laden water from the glacier. Moreover, for a year or two most of the glacier water has been diverted to Phelan Creek and thence to Delta River, so that only a very small part reaches the Gulkana. These conditions were reversed a few years ago, and doubtless will be again, for the river swings back and forth across the gravel bars as the débris from the glacier accumulates along the channel.

Three streams, fed by the melting ice of three large glaciers, unite to form the head of Susitna River. The water from this source is augmented by a number of smaller clear-water streams, including Boulder Creek, Valdez Creek, Windy Creek, and Clearwater Creek, and by a large glacial stream, Maclaren River. The part of Susitna River shown on the map flows over a broad gravel plain, but just west of the mapped area it makes a great bend to the right and flows westward for nearly 75 miles in a succession of rapids and smooth-water stretches through a narrow, mountain-inclosed valley.

The northern or high-mountain part of the district under consideration has a well-developed drainage system. Lakes are few, but streams are many and vigorous. The quantity of water in the run-off, like that of all glacier districts, depends on the season of the year, local weather conditions, and the time of day; in other words, it depends largely on the amount of glacier ice melting, as well as on the rainfall.

The southern lowland district, on the other hand, including most of the Gulkana drainage and a part of the Susitna drainage not represented on the map, is poorly drained. It is a lake country with a great area of marshy land, crossed by a few deep, sluggish streams. From any elevated point around its border hundreds of small lakes can be seen, and a journey across the lowland in summer involves continuous effort to avoid wet ground. All these small lakes, as well as the Susitna lakes, including Lake Louise, which is drained by Tyone Creek, and the large unnamed lakes between Lake Louise and Gulkana River, owe their existence to the lack of a well-developed drainage system. The streams have not yet intrenched themselves deeply enough into the gravel plain to drain away the water that accumulates on its surface.

CLIMATE.

The climatic conditions of the upper Susitna and Copper River regions that are of most interest to miners and prospectors have to do with the length of the summer and winter seasons, the variations of temperature, the amount of precipitation, and the proportion of fair or stormy days. These conditions can be described here only in a general way, because no weather records are available for more comprehensive discussion.

For practical purposes the year may be regarded as made up of an open season—summer, and a closed season—winter. The length of these seasons differs slightly in the mountain and lowland districts, the summer being a little shorter and the winter a little longer in the mountains than in the open country. Mining is begun on the placer claims along Valdez Creek early in June. Those who have horses leave the creek by September 10, in order that they may reach the coast before grass fails. Others stay a few weeks longer and go out with dog teams on the first ice of November. From 90 to 100 days, therefore, are available for mining operations and the rest of the year may be said to be winter. Underground mining, of course, can be carried on through the whole year.

Ranges of temperature in this interior region are great. The mercury sometimes falls to 40° or 50° below zero on the coldest winter days and sometimes rises to 85° or more in summer. A temperature of 94° has been known at Copper Center. Most of the summer days, however, are comfortably cool, and many of the nights are cold.

Snow may fall on the higher mountain tops at any time of the year, but in summer precipitation in the valleys is in the form of rain. During the months of August and September rain in the valleys is nearly always accompanied by snow on the mountain tops, but such snow usually disappears within a few hours. A few inches of snow covered the valley of Valdez Creek on September 1, 1910, but doubtless soon melted. A heavy snow that remained till the following spring fell at Paxson on September 17, 1909. These early snows afford good traveling, because they are not deep enough to make trail breaking difficult.

The amount of rain and snow that falls on the south slope of the Alaska Range is considerable, yet much less than that along the Pacific Coast of Alaska. Valdez Creek is regarded as a rainy district by the miners, although the precipitation there is probably less than it is farther east. Rainfall seems to vary much with local conditions, so that marked differences are noticed in localities only short distances apart; for example, it was said that the number of cold wet days in the summer of 1910 was greater at Paxson, on the military road, than at Myers, only 16 miles south at the edge of the foothills.

The rainfall at Gulkana and other points in the lowland along the military road is decidedly less than in the mountains; the grass on the benches dries before the end of summer, and it is necessary to provide some means to irrigate gardens. The snowfall of the lowland is also light. Snows come first in the latter part of September or early in October and remain till May, depending on the elevation above sea level and the character of the season. The heavy snows come late in the winter, and the miners endeavor to land supplies and other freight at the mining camps before the snow gets deep enough to be a serious obstacle to travel.

A record of the weather conditions, kept by the writer in the summer of 1910, covers 72 days, from June 28 to September 7, inclusive, and shows 28 days that were called fine, 16 that were fair, 7 that were cloudy all day, and 21 on which it rained part or all of the day. The summer of 1910 was regarded by the miners of the district as an unusually favorable season in respect to weather conditions.

VEGETATION.

It is not the purpose of this report to describe the vegetation of this district further than to give the more general facts concerning the distribution of timber and the supply of grass for stock.

Spruce is the only wood of particular value in the area visited. Cottonwoods grow along the lowland streams, and willows along the streams that extend above the limits of spruce in the mountain areas, especially along the bars of the creeks; but spruce is the important timber, both in respect to economic value and to distribution. Timbered areas as described here are in general, therefore, areas of spruce, and the timber line is the upper limit of spruce.

If a line is drawn across the map (Pl. I, in pocket) in an east-west direction through the middle of Gulkana Lake, it will represent approximately the northern boundary of the timbered country. Nearly all the country to the south is timbered land, and most of the country to the north is without timber, but there are a number of important exceptions to this general condition. Spruce grows scatteringly along the Susitna River as far north as the glaciers at its head, and small areas along the river are heavily timbered. Small patches of spruce are found, too, on the upper part of Clearwater Creek, on Maclaren River, to a point a few miles above the mouth of the west fork, and around the Tangle Lakes. Timber is present on Delta River at Garrett's cabin, on Phelan Creek, on Delta River northward from Phelan Creek, and north along Gulkana River to within a mile or two of Summit Lake.

The timber line ranges from 2,500 to 3,000 feet above sea level. It is commonly not higher than 2,500 feet in the lower country south of the middle range of mountains, but it reaches 3,000 feet at the head of Susitna River. Spruce timber is heavy on the south slope of the mountains between the two big glaciers at the head of Susitna River up to an elevation of 3,000 feet above the sea. Good timber also grows about the lower end of Valdez Creek, extending south along the lower hill slopes beyond Windy Creek. This is a fortunate circumstance for the miners, for it furnishes them with lumber and firewood almost at their doors. Timberline Creek, which enters Valdez Creek from the south about 2 miles above the mouth of Valdez Creek, was so named because it marks the eastern limit of spruce timber in the Valdez Creek valley.

Most of the streams are bordered with willows to an elevation considerably above the timber line. These willows are of great value to the traveler, for they provide the only firewood available in many places within the mountain area. Small willows and a dwarf birch, usually called " buck brush " in this region, grow on the lower mountain slopes and on the tops of the lower hills; but they are of no value to the miner and in many places are a serious obstacle to travel. The birch is especially troublesome because it grows so thickly as to form a tangle hard to penetrate; its stems, rough and crooked, hang together so that a pedestrian must exercise great care to prevent them tripping him or tearing his clothes, and at best make travel exceedingly tiresome. Alder is not so plentiful in this district as it is on the coast or in many parts of the Copper River and Susitna regions, yet there is a considerable growth in the vicinity of the Delta River forks and in a number of other places.

In the lowland areas spruce trees are intermingled with large cottonwoods along the streams and with groves of poplar or aspen on the higher land. The spruce does not attain as great a size on the open higher ground as along the stream channels, and the timber seen along the military road or in crossing the lowlands at other places is small. Many acres of it have been burned years ago, leaving the country covered with a forest of bare poles that fall as the roots decay and the wind overturns them. Extensive fires in the timber of the lowland area in the fall of 1910 destroyed many of the new bridges and culverts along the military road. Some of these fires were probably set deliberately, either to see them burn or to get rid of the mosquitoes, but probably most of them were due to carelessness in one form or another on the part of travelers. Settlers use the dry poles of the burned districts for firewood and for fencing, but most of it is practically valueless. In fact, it may be said of most of the lowland timber away from the stream courses that it is either of inferior quality or entirely unfit for lumber.

No attempt was made to collect or study the numerous grasses of the district between Gulkana and Susitna rivers. The supply and distribution of the grasses, however, are of great importance to the traveler with horses. Forage is scarce in the lowland district, although grass grows around some of the lakes and in places along the streams. Only a few places along the military road between Gulkana and Summit Lake afford enough grass for horses, so that travelers dependent on the country for supplies for their animals are obliged to make their camps according to the distribution of the grass and not by the length of day or the strength of the stock. On the other hand, grass is plentiful about the timber line in the mountain region, both in the stream valleys and on the hill slopes. In places the growth is luxuriant. Grass as high as a man's shoulder was seen on Valdez Creek where the brush had been burned off several years ago.

The end of the working season for many of the miners who use horses is determined by the severe frosts, because the horses are obliged to leave for the coast before the feed gives out. Most of the grass loses its value for forage as soon as frost strikes it. Although it appears to be good, horses eating it lose strength rapidly unless grain can be fed at the same time. According to Mr. A. J. Paxson, native grass for horse feed can not be depended on earlier than June 15 or later than September 5 in the vicinity of Gulkana and Summit lakes. In some years it may start earlier in the spring or live longer in the fall, but these dates define the limit of safety in that locality. The growing season is shorter than in the lowland, where grass comes up a week or two earlier and lasts about as much longer. The supply of native feed along the military road is less important now than formerly, for grain can be purchased at nearly all the road houses.

POPULATION.

The population of the district is small. The white population is confined to Valdez Creek and to a few localities along or near the military road. There are three military telegraph stations and nine road houses between Gulkana River and Canwell Glacier. At the three telegraph offices there are in all about a dozen soldiers, including operators and linemen belonging to the Signal Corps. The number of people, exclusive of transients, who live at each of the road houses ranges from two to six in summer, but is perhaps a little greater in winter. Between 20 and 25 men were mining on Valdez Creek in 1910, and about 10 more were either prospecting or mining in other localities. Thus it appears that the white population in the summer of 1910 was about 60 or 65 in all.

The district has a small native population, but no estimate of its number was attempted. Several of the Indian families have their winter quarters at Gulkana and others near Susitna River and the Susitna Lakes. One family lives on Valdez Creek. These families are widely scattered in the summer at the fishing stations along the rivers and later in the season in the hunting grounds. It is therefore difficult to get a correct idea of their number at these times, when little is seen of them on the regular lines of travel.

TRAILS AND TRANSPORTATION.

Transportation in this district, as in almost every other part of Alaska, is one of the most serious difficulties connected with mining.

In the early days supplies for use on Valdez Creek were freighted across Valdez Glacier to Klutina Lake and from there to Susitna River at the mouth of Tyone Creek, from which place they were taken over the river ice to their destination without serious difficulties. The most objectionable part of this route is Valdez Glacier, where the obstacles to be overcome are so serious that the route was given up as soon as the military trail was well established. The trail ascended St. Ann River, on the north side of Klutina Lake, crossed Lake Hudson, Taslina Lake, and the Susitna Lakes, and then descended Tyone Creek to Susitna River. The grades after crossing Valdez Glacier are not heavy.

Nearly all the supplies used on Valdez Creek for the last five or six years have been freighted over the military trail from Valdez to Gulkana, and thence to Valdez Creek by way of the west fork of Gulkana River and Maclaren and Susitna rivers. The difficulty of crossing the coast range by this route, as by the other, is serious and is one of the principal causes of the high cost of freighting into the Copper River basin, but improvements made from year to year on the military trail, which was at first suitable only for pack horses and narrow sleds, have transformed it into a road, which is practically ready for travel with wagons throughout its full length from Valdez to Fairbanks. A few large bridges and a number of culverts still remain to be completed, but doubtless most of them will be in place before the end of 1911. Ditching and grading will also be required on some stretches, but even in its present condition the road represents a great improvement over the old trail and reflects much credit on Col. Richardson and his associates of the Alaska Road Commission. During the summer of 1910 a new road was cut through from the military road to Chitina, the new town on the Copper River & Northwestern Railway, on the west side of Copper River, opposite the mouth of Chitina River. The new road branches off the old road at Willow Creek, about halfway between Tonsina and Copper Center. It runs east-southeast to Copper River and follows its west bank to the railroad. A bridge over Tonsina River, which was necessary to make this road available for general use, was completed in the winter of 1910–11.

The winter trail from Gulkana to Valdez Creek, as previously stated, follows Gulkana River to the head of its west fork, then passes the round-topped hill on the north by way of a low divide and comes out on Maclaren River about 7 miles from the Susitna. From the mouth of Maclaren River it follows the Susitna to Valdez Creek. The distance from Valdez to Gulkana is 128 miles, and from Gulkana to Valdez Creek approximately 125 miles. This trail, after the coast range is passed, offers very favorable grades for freighting. From Gulkana travel is almost continuously on the river ice, snowplows being used to break the trail ahead of the sleds. In favorable seasons travel is attended with little difficulty, but an effort is always made to reach Valdez Creek before the heavy snows of the late winter. This is accomplished more easily now than in former years, because the road through Keystone Canyon makes it possible to start from Valdez with freight before the river freezes in the canyon, thus saving a month or more at the beginning of the trip.

The cost of freighting from Valdez to Valdez Creek averages about 30 cents per pound. Under the most favorable circumstances it might be reduced to 20 cents, but the experience of several years has shown that 30 cents is not far from the average cost. It seems likely that the cost of freighting may be somewhat reduced with the opening for business of the Copper River & Northwestern Railway, but this will depend, of course, on the rates established.

Summer travel between Valdez Creek and the military road is over a somewhat different route from that followed in winter. The trail leaves the road at Bear Creek, about 1 mile south of Gulkana, and runs northwest to Maclaren River. It keeps to the east of the round-topped mountain between Maclaren River and Clearwater Creek, and leads to Valdez Creek by way of the Roosevelt Lakes pass. This trail is indicated on the map (Pl. I, pocket). Much of it is over wet ground, and travel with horses is so difficult that there has been a desire since the military road was put through from Gulkana to Fairbanks to find some shorter and better route connecting with it.

Two other routes have been tried. The more northern one is by way of Eureka Creek to the east fork of Maclaren River and thence across Maclaren River and its west fork to Roosevelt Lakes, west of Clearwater Creek. The other trail starts at Paxson and passes through the northern part of the Tangle Lakes district to the west fork of Maclaren River, from which point the trail is practically the same as the one just described. The distance is about 65 miles. The Eureka Creek trail is slightly shorter and crosses fewer ridges than that from Paxson; but it has the disadvantage of considerably increasing the total distance between Gulkana and Valdez Creek. Both trails are above timber line and the supply of firewood is limited to willows, so that neither route would be practicable for winter travel under present conditions, even if they afforded as favorable grades as the one now used. Either, however, would be a practicable summer mail route.

An attempt was made several years ago to establish a winter freighting route between Valdez Creek and Indian Creek, on Susitna River, but it was not found practicable at that time and there has been no attempt since then to renew it. A small amount of freight is brought from Fairbanks each winter by way of Nenana River.

GENERAL GEOLOGY.

STRATIGRAPHY.

INTRODUCTION.

The hard-rock formations of the region under discussion are complicated in structure and a clear understanding of their stratigraphic relations and areal distribution was not gained in the short time available for study in the field. They include both sedimentary and igneous rocks, and range in age from pre-Ordovician (?) Birch Creek schist, through Carboniferous or possibly earlier to upper Eocene.

GULKANA AND SUSITNA RIVER REGION.

In summarizing the general geology represented on the map (Pl. II, in pocket) it may be said that, aside from the Birch Creek schist, the rocks of this region which are thought to be oldest consist of greenstones, slates, tuffs, conglomerates, and quartzitic beds, together with a minor amount of limestone, all metamorphosed to a greater or less degree and locally changed into schists. These sediments, which are probably of Carboniferous age, form a belt extending east and west along the south flank of the high central part of the Alaska Range. (See Pl. II.) They were not fully differentiated from the massive rocks to be mentioned later. South of these sediments is a belt of heavy dark-colored, igneous rocks, consisting largely of amygdaloidal lava flows, with which is associated a minor amount of tuffs and tuffaceous conglomerates. The age of this succession of flows and tuffs is in doubt, but they are thought to be younger than the Carboniferous rocks previously referred to and older than the Upper Triassic rocks. Somewhat later than the extrusion of the lavas there was laid down a succession of slates, sandy shales, and limestone that contain fossils and are definitely determined to be of Upper Triassic age. Their distribution is only partly known.

The formations enumerated, which include everything in the region older than Eocene, are cut by granular intrusives, which are believed to be of Jurassic or later age. The most common and notable of these are diorites or quartz diorites and related granular and porphyritic rocks. They occupy a considerable proportion of the mapped area and are especially abundant in the vicinity of upper Susitna River.

They are not the only intrusives in the region, however, for dark basic dikes were seen at various localities. Lastly there was deposited a succession of shales, sandstones, and conglomerates of different degrees of consolidation, containing beds of lignite, and these are correlated with the Kenai formation of the Susitna Basin and are believed to be chiefly of Eocene age. Part of these beds, however, consist of unconsolidated deposits difficult to distinguish from the later unconsolidated Quaternary sands and gravels.

All the rocks mentioned have been folded and locally at least are much faulted. No unconformity in deposition was actually observed either below or above the Upper Triassic sediments, but the absence of upper Carboniferous and Lower and Middle Triassic deposits below and of later Mesozoic deposits above is attributed to erosion intervals during these times or to erosion intervals and faulting. Such erosion intervals might result in unconformity of deposition between the Carboniferous sediments and the lava flows, between the lava flows and the Triassic deposits, and between the Triassic and the Eocene deposits.

The following table presents in a somewhat different way the summary just given:

Geologic column of the upper Susitna-Gulkana district.

Quaternary:	
Recent	Stream gravels, sands, and silts.
Pleistocene	Glacial gravels and moraine deposits.
Unconformity.	
Tertiary:	
Upper Eocene (Kenai formation?)	Unconsolidated sand and gravel with lignite deposits. Sandstone, shale and conglomerate with lignitic coal beds.
Unconformity.	
Jurassic (?) or later	Granular intrusives, diorite, quartz diorite, and related forms.
Upper Triassic	Shale, sandstone, slate, arkose, limestone, tuffs, and lava flows.
Unconformity.	
Carboniferous or later	Basic lava flows, tuff, and tuffaceous conglomerate.
Carboniferous	Slate, tuff, quartzite, limestone conglomerate, and granular intrusives.
Probably pre-Carboniferous	Greenstones with some schist and granitic and basic intrusives.
Pre-Ordovician (?) (Birch Creek schist)	Highly altered sediments with igneous intrusives.

CHISTOCHINA DISTRICT.

It will be necessary in the pages that follow to make frequent reference to the work of Mendenhall[1] in the adjacent region on the east, and for that reason it is desirable to introduce here a summary of the geology described by him and to give a reprint of part of his geologic map (Pl. III, in pocket) in order that the areal distribution of the rock formations may be understood.

The oldest rocks represented on his map are micaceous schists that here make up the central part of the Alaska Range. They were mapped by him as the Tanana schist, but the "Tanana" schist has since been correlated with the Birch Creek schist, the older name, and "Tanana" has been abandoned. No conclusive evidence for the age of the Birch Creek schist has been found, but the formation is believed to be older than Ordovician.[2]

Next in order of age is the Chisna formation, which includes beds of quartzite, arkose, pyritiferous tuff, conglomerate, and limestone, and is cut by porphyritic dikes and igneous rocks, such as diabase and diorite. It is assigned to the Carboniferous on the basis of a few imperfect fossils and its probable stratigraphic position with reference to the formation next mentioned.

The Mankomen formation follows the Chisna in the stratigraphic column. It may be separated into two divisions, the lower of which is prevailingly arenaceous and tuffaceous and more than 2,000 feet thick, the upper prevailingly calcareous and approximately 4,500 feet thick. The total thickness of the Mankomen is therefore about 6,500 feet. It includes beds of sandstone, shale, limestone, quartzite, and tuffaceous sandstone, intercalated with flows or intrusive sheets of diabase and andesitic lava. Fossils collected from the Mankomen at different localities place the time of its deposition late in the Carboniferous. Originally the fossils were determined as Permian (latest Carboniferous), but later work in other parts of Alaska has led to the belief that they are really Pennsylvanian, and that the Mankomen formation, together with other sediments at the head of White River and on the Yukon at Nation River, are to be correlated with and are related to upper Carboniferous sediments in the Ural Mountains of Russia.

The Gakona formation of Mendenhall is much younger than the rocks just described. It is of upper Eocene age, and consists of coarse conglomerate and soft gray or buff-colored shales interbedded with gravel, sand, and lignite beds. Marked differences exist in the degree of consolidation of the sediments comprising this formation.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No 41, 1905.

[2] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

The basal member is a thoroughly indurated coarse conglomerate, not less than 500 feet thick, underlying compact and fissile shales, above which are slightly indurated clays and sands topped by an iron-stained pebble bed or cemented gravel, the highest member recognized by Mendenhall. The total thickness of the beds included in the Gakona formation is estimated at not less than 2,000 feet. Fossil plants collected from these beds were pronounced by Dr. F. H. Knowlton to be typical of the Kenai formation (upper Eocene), which is of fresh-water origin.

Quaternary gravels and glacial deposits are widely distributed and complete the geologic section of sedimentary deposits in this district.

In addition to the numerous dikes and sills intruded into the Carboniferous sediments, two formations wholly of igneous origin are represented on Mendenhall's map of the Chistochina district. They are the Tetelna volcanics and the Ahtell diorite, regarded by Mendenhall as of upper Paleozoic age. The Tetelna volcanics consist largely of altered andesites intruded by basic dikes, for the most part of diabase, but in some places of diorite. The Ahtell diorite is a massive quartz diorite, pink or brownish red in color, and was considered by Mendenhall to be older than the Mankomen formation. Possibly, however, the diorite may belong to the period of Mesozoic intrusion, to be described later.

Structurally the Mankomen formation lies between the Birch Creek schist and the Chisna formation. It is separated from the Birch Creek schist by a great fault which finds expression in a prominent topographic depression, and from the Chisna formation by another fault, making it appear to have been dropped below its proper stratigraphic position. The displacement between the Mankomen formation and the Birch Creek schist is considered by Mendenhall to be not less than 10,000 feet. In general the beds of the Chisna formation dip southward, and those of the Mankomen dip to the north. A general southward dip is characteristic of the beds of the Gakona formation in their exposures between West Fork Glacier and Gakona Glacier, where they cap a high ridge and form the southern slope of the mountain.

These four formations include the most important rocks of the Chistochina district; all but the Mankomen are also represented in the district west of Gulkana River.

PRE-ORDOVICIAN (?) ROCKS.

BIRCH CREEK SCHIST.

A small area of Birch Creek schist along Delta River is represented on the geologic map (Pl. II, in pocket). It, however, is outside the district visited by the writer, and the description of the rocks found there is based chiefly on that of Mr. Capps,[1] who studied the geologic formations on the north slope of the Alaska Range between Delta River and the Nenana in this same year (1910).

A more general description of the Birch Creek schist is given by Brooks,[2] who describes it on his geologic map as consisting of "Micaceous, graphitic, garnetiferous quartz schists, and schistose quartzites with some limestones, also including some greenstones and other igneous rocks, locally mineralized and auriferous."

The known areas of Birch Creek schist extend eastward in the region north of the Alaska Range from the vicinity of Mount McKinley into Yukon Territory. Capps describes the formation where studied by him as showing much variation in the character of its component members, yet distinctive as a whole and easily recognized. Highly contorted and fissile mica and quartz schists and phyllites, green, red, brown, or gray in color, are the predominant rocks. In a few localities the fresh unaltered rocks are comparatively massive and mica is inconspicuous, but in weathered outcrops the fissility is made prominent and the large amount of mica present gives the surface a glistening silvery luster. Oxidation of the iron pyrite changes the prevailing green color of the original rock to red or brown in weathered exposures. Variation in the degree of schistosity is the rule rather than the exception, some of the rocks, as previously stated, being massive and without well-developed cleavage, while others split readily owing to the large amount of mica present. Beds of metamorphosed quartzite are interbedded with the mica schists, in places showing an imperfect cleavage due to the development of mica scales. Dense beds of graywacke and fine black slate or slaty schist are also associated with them. Quartz-mica schist predominates in the district west of Little Delta River, but in the vicinity of Mount Hayes the less metamorphic quartzitic and slaty schists become important, so that the whole succession more nearly resembles that of the type locality north of Fairbanks. On Delta River quartz-mica schist forms an important part of the stream wash and is believed to be well developed, although Capps was unable to study the area carefully.

The Birch Creek schist is intruded by a variety of igneous rocks ranging from greenstones and hornblende rocks to more acidic varieties and varying in texture from fine-grained cherty types to granite porphyries. These intrusives differ widely in metamorphism also, for some are entirely fresh, while others show almost as great alteration as the inclosing schist. Capps believes that the Birch Creek schist in this area is derived chiefly from clastic sediments, but shows that igneous members were associated with them also.

---

[1] Capps, S. R., jr., The Bonnifield region: Bull. U. S. Geol. Survey No. 501, 1912, p. 20.

[2] Brooks, Alfred H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 56–60.

The members of the Birch Creek schist have been closely folded and intensely metamorphosed, so that the structure is intricate and difficult to determine. In most places the bedding is obscured by the schistosity, yet the major structural features may be made out from a study of large masses of the rocks, and it is seen that the strike of the beds is roughly parallel to trend of the Alaska Range, while the dips of the beds range from 15° to 60°.

AGE.

The age of the Birch Creek schist has not been determined. No fossils have been found in it. It appears to be overlain unconformably by a succession of quartz feldspar schists containing slates and a little limestone that is considered by Brooks[2] to be of Silurian or Devonian age. He regards the Birch Creek schist, therefore, as probably pre-Ordovician.

PROBABLE PRE-CARBONIFEROUS SEDIMENTARY ROCKS.

DISTRIBUTION AND CHARACTER.

About a mile north of Myers road house on the military road there is an area of greenish mica schist cut by light-colored granitic intrusives and by dikes of dark, heavy, basic rock. The granitic intrusives are sheared and have a definite cleavage, but the dark-colored dikes are fresher and apparently younger. The exposures are too poor and the examination was too brief to yield definite information, but the schists show much greater metamorphism than the nearest Carboniferous sediments toward the north nearer the zone of more intense folding in the Alaska Range.

In the vicinity of the Tangle Lakes similar schists are intruded by dikes of light-colored, fine-grained rock, containing small hornblende phenocrysts, probably related to the diorite.

The schists of these two areas lie south of the principal zone of lava flows and are thought to be part of a larger area of schists and associated igneous rocks, chiefly greenstone and diorite, that form the low rounded hills at the northern border of the Copper River lowland.

AGE.

Any estimate of the age of the schists would be little more than speculation. So far as the degree of metamorphism is of value in determining age it indicates that the schists are older than the nearest Carboniferous sedimentary formations toward the north (at the head of Gulkana River), which are so situated with reference to the axis of the Alaska Range that a greater degree of folding and more pronounced schistosity would be expected in them than in the schists if the disturbances that produced the range accounted alone for the alteration in both. Local schistosity, however, is not uncommon in the Carboniferous deposits.

---

[2] Brooks, A. H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

CARBONIFEROUS ROCKS.

Under the heading "Carboniferous rocks" are grouped a number of formations of widely different character. They consist of sedimentary deposits, such as conglomerates, limestones, quartzites, volcanic tuffs laid down in water, and intercalated lava flows or intrusive sheets. The age of the sediments may be referred to Carboniferous time with considerable, but not absolute, certainty. The massive Carboniferous limestones have been distinguished from associated rocks on the geologic map (Pl. II, in pocket), although they are not treated as a distinct formation in the text. The basic lavas and tuffs are referred to the Carboniferous with less certainty, and they may prove to be of Triassic age.

SEDIMENTARY DEPOSITS.

CHARACTER AND DISTRIBUTION.

East of Phelan Creek and west of Delta River northward from Eureka Creek to Canwell Glacier, the high mountains consist of slates, tuffaceous beds, quartzitic sediments, and local limestone beds associated with diabasic flows or intrusions and with light gray or greenish gneisses that probably represent metamorphosed diorite intrusions. These beds are much folded and in places a schistose structure has been developed. The weathered surfaces of many of them have a rusty red color that renders them particularly conspicuous and makes them recognizable at long distances. The same rocks extend eastward to the Chistochina River region, where they were named the Chisna formation by Mendenhall, and westward on the north side of Eureka Creek to at least as far as the glacier at the head of the main fork of Maclaren River. Whether they continue west to Susitna River was not determined, but it is thought probable that they may extend even farther westward into the headwater region of Nenana River.

In the vicinity of Canwell Glacier and eastward the Carboniferous deposits abut against the Birch Creek schist on the north, this position being due to a profound fault whose extension and location west of Delta River is not known. The possibility that the rocks described as Carboniferous include some infolded Mesozoic sediments will be discussed in the description of the Triassic deposits.

AGE AND CORRELATION.

The evidence for the age of the Carboniferous sediments is not sufficient to determine definitely the time at which they were deposited. The only fossils collected are crinoid stems from the massive limestone beds outcropping east of Gulkana Glacier and on Eureka Creek, and the evidence they afford is merely presumptive. No fossils were obtained from the other sedimentary beds here referred to the Carboniferous.

Some light is thrown on the problem by the relations existing in the region immediately east of that under consideration. Mendenhall[1] found a great thickness of Carboniferous strata in the headwater region of Chistochina River and divided them into the two formations which he named Chisna and Mankomen.

Parts of the Mankomen formation are abundantly fossiliferous, and on the basis of the fossil determinations the formation was originally referred by Schuchert to the Pennsylvanian and then to the Permian, but was later reassigned to the Pennsylvanian by Girty and is correlated with the Pennsylvanian of the White River region[2] and with the Nation River formation[3] of the Yukon. Girty's determinations show the fauna of these localities to be unlike that of central and eastern North America and to represent the Russian Gschelian of the Ural Mountains.

Mendenhall correlated the tuffaceous beds of Phelan Creek with the Chisna formation, and there can be little doubt that the correlation is correct. The Mankomen formation, however, appears to have been faulted out, for no evidence of it has been recognized west of Gulkana Glacier. Mankomen fossils abound in the high mountain east of the lower end of Gulkana Glacier some distance above the massive limestone bed there exposed, but all collected were from loose material on the mountain slopes, and it was considered quite possible in the field that the material was not in place, but came from somewhere nearer the head of the glacier. No similar fossils were found west of Delta River. The best available evidence for the age of the rocks north of Eureka Creek, here correlated with Mendenhall's Chisna formation and referred to the Carboniferous, indicates that they are older than the Mankomen formation. It is entirely possibly, however, that more field work would have shown that they include Mesozoic sediments, such as were found farther west in the neighborhood of Valdez Creek but were not recognized east of Maclaren Glacier.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 33 and following.

[2] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: Bull. U. S. Geol. Survey No. 417, 1910, p. 17.

[3] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 291–304.

In a broader way Brooks[1] has correlated the Chisna formation with the Cantwell formation at the head of Nenana River, the Wellesley formation on White River, and the Nation River formation of the Yukon. The Cantwell formation, as described by Brooks, is a massive quartz and chert conglomerate, with brown sandstone interbedded with black clay shale and volcanic rocks. It has a thickness of more than 3,000 feet and is provisionally assigned to the Carboniferous on stratigraphic and not on fossil evidence. If this assignment proves correct, Carboniferous sediments form an important part of the Alaska Range, at least from Mentasta Pass to Nenana River.

BASIC LAVAS AND TUFFS.

CHARACTER AND DISTRIBUTION.

The belt of heavy, dark-colored, volcanic rocks extends from the vicinity of Summit and Gulkana lakes westward beyond Susitna River. These rocks consist largely of diabase and locally are amygdaloidal, showing that in part, at least, they are surface lava flows. They are associated with argillites, tuffs, and tuffaceous conglomerates in a number of places and are intruded by diabases and by dikes of less basic, light-colored porphyritic rock. Intrusions of peridotite have taken place in the Tangle Lakes vicinity and probably also in other places, for bowlders of this character were found in some of the younger conglomerates near the glacier at the head of the east fork of Maclaren River. The lava flows have been deformed in the general folding of the region so that steep dips are common, and schistosity is occasionally developed. These flows form a prominent range of mountains parallel with the axis of the Alaska Range and not sharply separated from it in the vicinity of Maclaren River. This secondary range is characterized by sharp angular outlines, due chiefly to recent glaciation but probably dependent also on the nature of the rock forming it (Pl. V, *A*, p. 40). The main belt of these volcanics is at least 15 miles wide on the east side of Maclaren River, and isolated hills and another lower range made up in large part of similar rocks lie to the south and are perhaps a part of the same succession of flows. A great difference in the appearance and amount of alteration at different localities suggests that the volcanic outbursts were intermittent during a long period, but the field studies were not sufficient to prove that such differences exist within the main belt of volcanics.

AGE.

The evidence available as to the age of the basaltic lavas is not sufficient definitely to determine the geologic time in which the flows took place and possibly not even the relative age of the flows and of the sedimentary formations with which they are associated. The circumstances from which the conclusions of the report are deduced are as follows:

---

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 83.

Near the mouth of Eureka Creek a succession of limestone beds, black and gray slates, and associated diabases, dipping 40° to 50° S., appear to pass beneath lava flows and are, therefore, supposed to be older. A possibility of error, however, lies in the fact that the exact relation between the sediments and the lava flows is not known and that faulting or an overturned fold may have obscured the facts. Southern dips of the lava flows were observed at other localities, particularly on Maclaren River, but in none of these places were conditions for observation so favorable as on Eureka Creek.

The mountains west of Clearwater Creek and south of the pass to Valdez Creek are made up in part of lava flows and in part of sedimentary deposits which include a number of small limestone beds containing Upper Triassic fossils. In several places these limestone beds overlie the basic eruptive rocks and both eruptives and sedimentary beds dip to the north. Here again the exact nature of the contact relation between the two formations is in doubt, but the evidence at hand seems to indicate that the sediments are younger than the volcanics. It therefore appears probable that the lavas were poured out either in late Carboniferous time or during early or Middle Triassic time.

In this connection it may be stated that the massive Carboniferous limestone of the upper White River corresponding to the Mankomen formation is underlain by Carboniferous shales, tuffs, and lava flows and is overlain by similar rocks in which the lava flows predominate greatly. In the Chitina Valley the Upper Triassic Chitistone limestone rests on several thousand feet of diabasic lava flows known as the Nikolai greenstone. The lava flows of Eureka and Windy creeks resemble the Nikolai greenstone both in character and in their relation to the associated Triassic sediments and suggest a strong probability that their extrusion was approximately synchronous.

On the other hand, a large area of Middle Jurassic volcanic rocks in the Talkeetna Mountains just south of Susitna River and much nearer the region under consideration than the Wrangell Mountains, differ from the volcanic rocks along Windy Creek and south of Eureka Creek in the important respect that they consist of less basic materials, being made up of andesite greenstones, dacites, rhyolites, and associated tuffs. For this reason and for the stratigraphic reasons already given it is thought that the lavas of Windy Creek are not equivalent to those of the Talkeetna Mountains.

TRIASSIC ROCKS.

CHARACTER AND DISTRIBUTION.

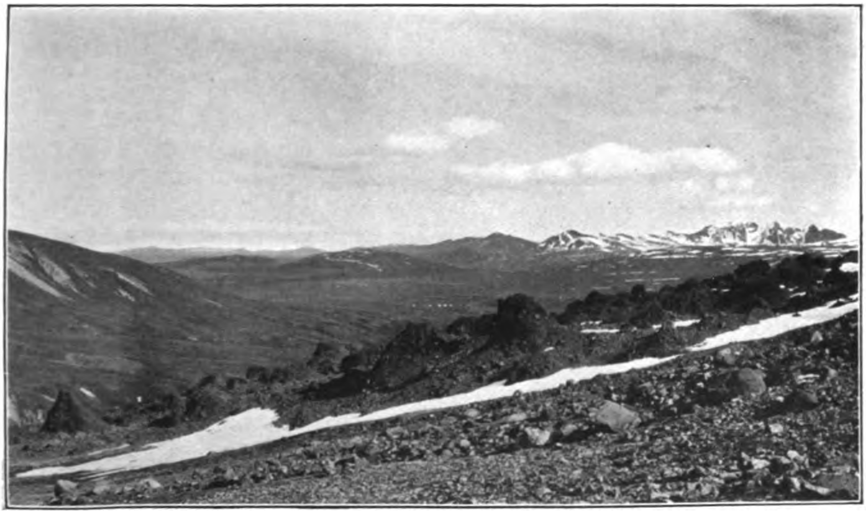
On the south side of Coal Creek, a tributary of the Clearwater, several hundred feet of horizontal, thin-bedded, shaly limestone and calcareous sandstone are exposed, extending from the creek nearly a third of the way up the mountain. The main mass of the mountain consists of basalt, against which the sediments abut in such a way as to suggest that the contact relation is due either to faulting or to unconformity of deposition. The limestone fragments show numerous Upper Triassic fossils. Many bowlders of black fossiliferous limestone are found in the creek bed and are probably derived from a bluish-gray limestone, not less than 60 feet thick, overlain by red weathering shaly or tuffaceous rocks, which appears in the lower part of the mountain on the north.

West of Clearwater Creek and south of its tributary which heads near the Roosevelt Lakes bluish-gray limestone beds yielding Upper Triassic fossils were found in several places resting on the volcanic rocks. They are little metamorphosed and are associated with banded slates, black slates, red weathering slates or shales, graywackes or fine tuffs, tuffaceous conglomerates, and diabase flows or intrusions. In general the beds dip north. They are intruded by diorite and related hornblende porphyries and feldspar porphyries. Fossiliferous limestone is exposed in one of the gulches on the north side of the creek heading near the Roosevelt Lakes, and although the fossils collected yielded no evidence as to the age of the limestone this is thought to belong with the Triassic sediments to the south. It appears, therefore, that except for this one undetermined outcrop the known fossiliferous Triassic sediments are near the boundary of the belt of lava flows. A number of limestone outcrops near this boundary, north and northeast of the head of Windy Creek, differ slightly in appearance from the beds previously mentioned and may possibly be of different age, although the only reasons for such an assumption at present would be that the limestone is crystalline in character and apparently contains no fossils. The presence of intruded igneous rocks in the vicinity, however, is believed to explain sufficiently the alteration of the limestone and the absence of fossils, for the recrystallization of the limestone would tend to destroy any animal remains that might have been present.

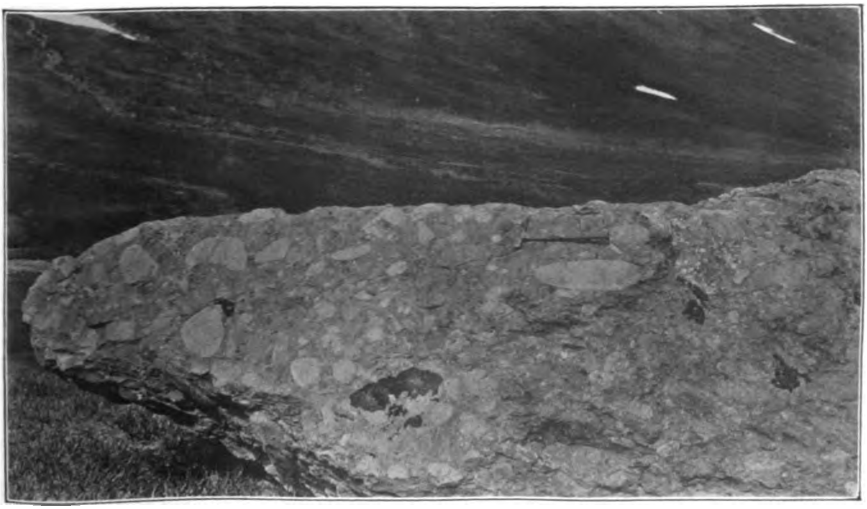
The heterogeneous character of the rocks associated with the Triassic limestones and the rocks immediately north of the limestones and apparently overlying them, especially a massive conglomerate a mile or more southeast of the Roosevelt Lakes, suggests the presence of younger Mesozoic or possibly Tertiary sediments in this region, but no fossils were found to support this possibility. The best exposure of this conglomerate is in the mountain between the branch of the tributary of Clearwater Creek heading against Windy Creek and the branch heading toward Roosevelt Creek. The western face of this mountain is a massive conglomerate made up almost entirely of igneous rocks, chiefly dark, basic volcanics, but with a considerable amount of granitic rock in a groundmass of tuffaceous material. The pebbles and cobbles are well rounded and many of them are a foot or more in diameter (Pl. IV, *B*). This conglomerate, although it forms a large part of the mountain, is restricted to a small area, probably less than 2 square miles. No similar conglomerate was seen at any other locality during the summer.

The belt of rocks included between Valdez and Windy creeks on the west and extending eastward along the boundary of the lava flows to Maclaren Glacier includes an assortment of rock types that confuses and hides the main geologic facts. This belt includes the Triassic limestone beds and the conglomerate just described, but consists largely of slates and intercalated basic igneous flows or intrusives, all of which are cut by granular intrusives of dioritic or related characters. They differ from the rocks bounding them on the north in that they show less metamorphism, the sediments being changed to slates rather than schists and the diorites being little altered, thus presenting a strong contrast to the schistose and gneissic diorite north of Valdez Creek. These differences are brought out in the area north and west of the head of Clearwater Creek, where the slightly altered graywackes and shales or slates are in contact with schistose diorite, a relation which may be due either to faulting or to depositional unconformity, but which, from the seeming absence of conglomerate or sandstone, is probably due to faulting rather than to deposition. Unconformity of deposition or faulting would also account for the difference of metamorphism in the slates south of Valdez Creek and the schists north of it.

The hills immediately north of Valdez Creek consist of schistose sedimentary rocks and much-altered diorite intrusives. Schistosity is greatest in the vicinity of the diorite, particularly around the borders, where thin dikes or sills have been forced into the sediments along the bedding or cleavage planes, and is accompanied by the formation of garnet and kyanite. Kyanite is a mineral characteristic of the highly metamorphic sediments and is believed to be formed under deep-seated conditions of high pressure and temperature. At the time this locality was visited it was supposed that the schists represented a local advanced state of metamorphism in the general slate area of Valdez Creek, due to the intrusion and immediate presence of the diorite, but the possible existence of the fault previously mentioned places the supposition in doubt and makes it possible that the schists north of Valdez Creek and the slates south of it are not uivalent. With the evidence now at hand it is impossible to



A. LANDSLIDE ON NORTHERN TRIBUTARY OF EUREKA CREEK.



B. CONGLOMERATE ASSOCIATED WITH TRIASSIC SEDIMENTS BETWEEN ROOSEVELT LAKES AND BIG CLEARWATER CREEK.

determine whether the schist area should be mapped as part of the Carboniferous rocks to the east, as part of the Triassic sediments, or as differing from both.

AGE AND CORRELATION.

The age of the Triassic rocks was determined on the evidence of the fossils collected from them and submitted to Dr. T. W. Stanton for identification. The substance of his report follows, the numbers given to the three lots being those of the National Museum:

No. 6570.—Limestone area on a small western tributary of Clearwater Creek.

Halobia sp. related to H. superba Mojsisovics.
Tropites sp.
Discotropites? sp.
Arcestes sp.

These fossils belong to the Upper Triassic fauna.

No. 6571.—Coal Creek, a tributary of Clearwater Creek, 15 miles east of Susitna River.

Pseudomonotis subcircularis (Gabb).

This is a characteristic Upper Triassic species.

No. 6572.—West of Clearwater Creek, about 2 miles northwest of the locality from which No. 6570 was taken.

Serpula sp.

Horizon not determinable from this fossil.

The first two lots of fossils show that the Triassic limestones of this region are equivalent in age to the Chitistone limestone and the McCarthy shale of the Chitina Valley and with the Triassic limestone of the Nabesna River region. Upper Triassic sediments in Chitina Valley attain a thickness of not less than 6,000 feet, of which the lower part, known as the Chitistone limestone, comprises 3,000 feet. The thickness and areal extent of the Triassic sediments in the Nabesna region is unknown.

Upper Triassic deposits are also found in the Cook Inlet and Alaska Peninsula regions.[1] They consist of thin-bedded cherts, limestones, and shales generally much contorted and containing many intrusive masses. The base of the succession has not been observed.

A large proportion of the known Triassic deposits of Alaska lie south of the Alaska Range, and future work will probably show that they have considerable development in the upper Susitna region, as well as the Cook Inlet and Chitina River regions.

JURASSIC (?) ROCKS.

CHARACTER AND DISTRIBUTION.

The Jurassic, if present in this part of the Alaska Range, is represented by igneous rocks. No sedimentary deposits are known here that can with much certainty be referred to the Jurassic period, notwithstanding the fact that both sedimentary and igneous rocks of this age are widespread in the Talkeetna Mountains, only a short distance southwest, and are found in other parts of the range.

---

[1] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, 1905, p. 410.

The rocks tentatively referred to the Jurassic, chiefly quartz diorites and related granular intrusives, occur as dikes, sills, and large masses of irregular form intruded into the older sedimentary and igneous rocks. True granites were not found in the region studied.

The diorites are prevailingly gray in color and differ considerably in alteration. In some exposures they appear to be perfectly fresh, but in others they show well-developed cleavage and are schistose. Examination with the microscope shows that the typical diorite of the region is composed essentially of soda-lime feldspar, hornblende, biotite, and quartz. Hornblende is more plentiful than biotite in nearly all the specimens examined. Pyroxene is generally present and alters to hornblende. Both hornblende and biotite alter to chloritic material. Other secondary minerals are epidote and zoisite. Titanite, apatite, magnetite, and pyrite are accessory minerals. Such intrusives are widely distributed near the head of Susitna River, and are believed to be connected with the source of the gold on Valdez Creek.

Most of the smaller masses, such as dikes and sills, have a porphyritic structure. A few of the dikes show large phenocrysts of feldspar, but hornblende porphyries are far more common. There seem to be all gradations between quartz-hornblende, diorite, and rocks consisting almost entirely of hornblende. A specimen of this last type, found in the mountains between Roosevelt and Windy creeks, consist of large blade-like crystals of hornblende in which are scattered grains of feldspar, apatite, and magnetite. A little vein of epidote cuts the hornblende in one specimen. This dark hornblende rock is present at many localities in the Alaska Range between Susitna River and Chistochina Glacier.

Diorite intrusives are common at many places in the district, as is shown by the geologic map (Pl. II, in pocket). They cut the Triassic sediments, and are, therefore, younger, but they do not appear in the Tertiary deposits. On the north side of Valdez Creek they intrude slates and show a great number of apophyses extending as sills and dikes from the main mass of the intrusive into the sediments. Both the intrusive and the host have since undergone further alteration, for the diorite is schistose, but there may have been considerable contact-metamorphic action at the time of intrusion. The slates in the vicinity of the contact are much altered and have developed in them a great deal of garnet and kyanite. Kyanite, though it is generally a product of dynamic metamorphism and is usually found in the crystalline schists, occurs locally in contact-metamorphic zones.

AGE OF THE DIORITE INTRUSIVES.

The principal evidence as to the age of the diorite found in this region is the fact that it intrudes the Upper Triassic sediments, but has not invaded the upper Eocene deposits. On this evidence, therefore, it is younger than Upper Triassic and older than upper Eocene. Paige and Knopf[1] have presented evidence to show that the quartz diorite intrusions of the Talkeetna Mountains are younger than Middle Jurassic and are contemporaneous in a general way with the great series of intrusions that affected the whole cordilleran region of North and South America. Brooks and Prindle[2] consider the period of intrusion to have been post-Middle Jurassic and to have extended into the Cretaceous. The diorite intrusions of the Chitina Valley are younger than Upper Jurassic, for they cut the Kennicott formation, which is probably of Upper Jurassic age, and possibly extend into the Cretaceous.[3]

It appears probable that the dioritic intrusions of the upper Susitna region may have extended over a considerable length of time, as is suggested by the different degrees of alteration which the intruding rocks present, and that they are to be referred to the late Jurassic and early Cretaceous epochs.

TERTIARY ROCKS.

CHARACTER AND DISTRIBUTION.

A small creek that comes down from the mountain on the east and joins the Gulkana Glacier stream a short distance below the south end of the glacier has cut its channel in a succession of folded conglomerates and partly indurated clays with which are interbedded thin seams of coal ranging in thickness from a fraction of an inch to 3 inches. The clays are banded and show fragments of plants. This succession of sedimentary beds strikes east and west and dips steeply to the north. With it are associated soft, highly-colored clays, yellow, white, and bluish gray, which extend up the hill on the north to a point several hundred feet above the creek.

The hills east of the part of Gulkana River between Summit Lake and the glacier show bluish-gray clays in some of the stream cuttings, but are made up in large part of consolidated sands and gravels, tilted at angles as great as 45° to the horizontal. In many places they contain beds of carbonized wood or lignite. Gravels of this character are exposed on both sides of Isabel Pass and seem to extend up the mountain on the north side to an altitude of nearly 2,000 feet above the creek, or almost to the summit. The high mountain east of the south end of Gulkana Glacier appears to be made up of a massive but poorly consolidated conglomerate containing a great many fossiliferous fragments from the Mankomen formation.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 20.

[2] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 117 and 153.

[3] Moffit, F. H., and Capps, S. R., The geology and mineral resources of the Nizina district, Alaska: Bull. U. S. Geol. Survey No. 448, 1911, p. 38.

The tributary of Phelan Creek on which the road house and the military telegraph station are located cuts a deep canyon in a high bench flanking the mountains on the east. In the lower part of this canyon the wall rock consists of brownish-yellow conglomerate interstratified with thin sandstone beds (Pl. IX, *A*, p. 60). The conglomerate is firmly cemented and confines the creek between vertical walls, but it can be readily broken down with the pick. It strikes N. 65° W. and dips 20° to 30° NE., in contrast to the gravel and sand beds south of Isabel Pass, which dip 45° S. Associated with the conglomerate and sandstone are several hundred feet of unconsolidated sands and gravels, separated from the conglomerate by a north-south fault. Apparently the unconsolidated material, which is composed of gray clays, pure white quartz sands of exceedingly fine grain, and beds of lignite up to 2 and 3 feet in thickness, is the lower part of the succession of beds to which the conglomerate belongs. The lignite beds are filled with sand and resemble broken driftwood accumulations on a beach. Carbonization of the wood has advanced only a little way and the woody structure is distinctly visible, so that the pieces resemble charcoal rather than coal. All these deposits are overlain unconformably by glacial till and gravels.

Yellow conglomerates like those described are exposed on Delta River below Wild Horse Creek and in the hill between Phelan Creek and Delta River. In fact this hill appears to be almost made up of Tertiary deposits, covered by a thin veneer of glacial till.

Rocks referred to the Tertiary were found at two localities west of this point. The first of these is north of the head of Eureka Creek. On a small tributary heading in the mountain east of the glacier from which Eureka Creek flows yellow iron-stained conglomerate and sandstone like those previously described are exposed. This outcrop appears to be small, but on the west side of the same stream near its head are other rocks of very different appearance that are probably of equivalent age. The south end of the mountain between this stream and the glacier is capped by a massive, loosely cemented conglomerate made up almost entirely of igneous rocks, most of which are derived from the basaltic hills to the south. There is, however, a small proportion of granitic material. Many bowlders in the conglomerate reach a diameter of several feet. The whole deposit weathers to rusty red and shows an abundance of iron oxide. Apparently a landslide has taken place here, or possibly from time to time the conglomerate has broken off in large masses from the mountain top and rolled down the eastern slope, for an area of perhaps 20 acres is covered with immense blocks of conglomerate, some of which are 30 or 40 feet long (Pl. IV, *A*, p. 32). They break down rapidly under the influence of the weather and form immense heaps of loose bowlders and iron-stained gravel.

The second western locality is on the south side of Coal Creek near its head, where an exposure of coal 5 or 6 feet thick, associated with yellow shales, stands vertically. The coal and shales are so folded, crushed, and faulted that it is difficult to find a good firm piece of either. A fault on the north side of the coal, running N. 65° W., marks the course of the bed. The exposure is not more than 100 feet long, but the coal blossom is seen along the creek for at least half a mile farther east and is nearly everywhere associated with yellow and white clays like those found on Gulkana River. The coal of this locality is entirely different from any previously mentioned; it does not have the woody character and contains no sand. Apparently the bed was originally a clean deposit that has since been much folded and broken. It is similar to the coal described by Mendenhall as occurring in the bed of Slate Creek,[1] and like that seems to be a remnant of the Tertiary folded into the older rocks.

These areas include all the observed deposits thought to belong in the Tertiary, but it is highly probable that such deposits are more extensively developed in this region. The largest area is that around the heads of Delta and Gulkana rivers, which comprises the western extension of Mendenhall's Gakona formation.

One of the important features of the Tertiary deposits as described is their separation into an underlying succession of fairly well consolidated material and an overlying succession of unconsolidated material. Firm beds of conglomerate may be locally interbedded with unconsolidated sands and gravels, but the distinction indicated seems to be well founded. Both consolidated and unconsolidated beds are much folded, but if a generalization can be made from the examination of so few localities it appears that the consolidated material has suffered most. Detailed work on the Tertiary deposits of the region would doubtless result in a distinction being made between the two divisions here considered together.

The character of the unconsolidated upper part of the Tertiary deposits make it impossible in reconnaissance work of this nature to differentiate them from the younger sands and gravels produced and laid down during the time of glaciation. In mapping areas of this kind, therefore, uncertainty exists as to whether gravels such, for example, as those at Paxson should be assigned to the one formation or to the other. Part of these bench gravels are undoubtedly of glacial origin, but it is possible that the remainder belong among the unconsolidated Tertiary deposits.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 53.

AGE AND CORRELATION.

No fossils were collected for determination from the sedimentary deposits referred to the Tertiary. Fragmentary plant remains were found at a number of places and lignitic coal is common. The lithologic similarity of these deposits with the coal-bearing beds of the Kenai formation of the Cook Inlet, Susitna River, and Copper River basins, and of the north side of the Alaska Range is the principal reason for referring them to the Tertiary.

Mendenhall found sedimentary deposits of this age well developed on the east side of Gulkana Glacier and called them the Gakona formation.[1] The Gakona formation consists of a succession of fresh-water deposits, including a massive conglomerate which appears to be overlain by soft, gray, or buff-colored shales associated with beds of gravel, sand, and lignite. (See p. 23.) Mendenhall found marked differences in the degree of consolidation of the material making up the formation. The basal conglomerate and the shales resting on it are indurated; the higher beds, however, are only slightly indurated, and he describes the highest recognized member of the formation as a cemented gravel.

These rocks extend west along the flank of the Alaska Range at least to Delta River and occupy an area much greater than in the Gakona type locality. Careful work would probably show that they are more widely developed in the valley of Eureka Creek than they are now known to be. The soft yellow conglomerate and sandstone described as occurring at the head of Eureka Creek is similar to that of Delta River and Phelan Creek, but the beds on Coal Creek probably belong among the basal beds if they are correctly referred to the Tertiary. Coal alone does not afford conclusive evidence of the age of the beds, for coal occurs in the Jurassic deposits at the head of Matanuska River;[2] but in this particular locality it appears probable that a remnant of Tertiary beds has been caught and preserved in the folds of older rocks.

The Kenai formation (upper Eocene) has wide development on Cook Inlet, in the Matanuska valley, and in the valley of the Susitna, in all of which places it includes extensive coal deposits. It has also been recognized on the north side of the Alaska Range between Nenana and Delta rivers and in many other parts of Alaska.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 52.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, p. 56.

QUATERNARY DEPOSITS.

DEPOSITION.

The Quaternary deposits include unconsolidated materials laid down by ice and water during the glacial epoch and those since deposited by the streams. They include also unconsolidated material, such as talus slopes and mantles of rock waste on the hillsides, that has never been subjected to the action of glaciers, lakes, or streams; these, however, do not call for extended description here. In a region like this, where considerable glacial activity still prevails, a time distinction between glacial and stream deposits can not be drawn, for the ice still transports and deposits morainic matter just as it did when the glaciers were far more extensive, and the glacial débris is being sorted and resorted by the glacial streams just as it has been during all the time the ice has been present. The two processes of transportation and deposition by ice and by water have gone on side by side, and the products can not be absolutely distinguished.

GLACIAL DEPOSITS.

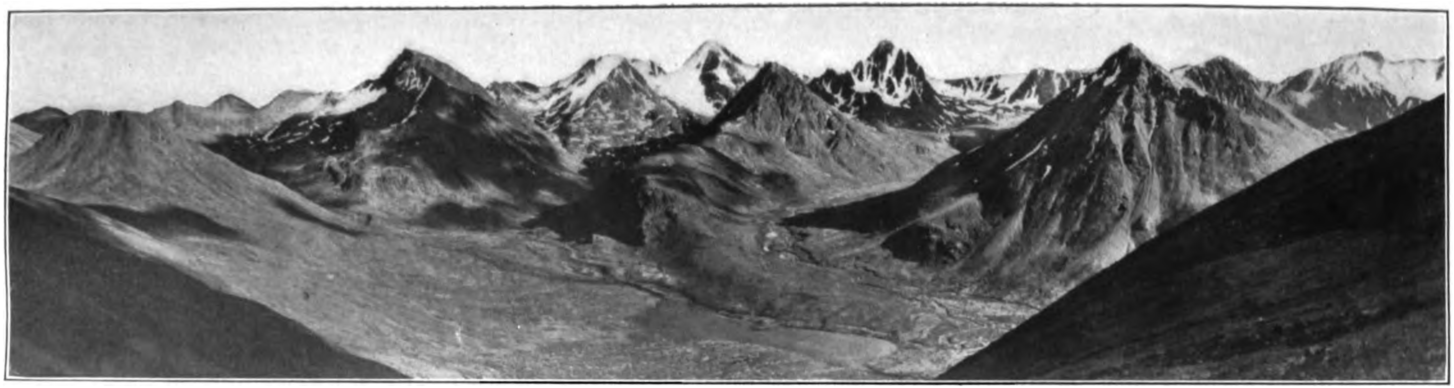
Two types of glacial deposits are easily distinguished in this region by those familiar with the character or topographic forms shown by glacial débris. The first is the ground moraine or till sheet, which forms a thin veneer over the underlying formations and is widely distributed in the northern part of the area, particularly over the more level parts, such as that of the Tertiary formations at the head of Delta and Gulkana rivers. Such deposits do not always assume conspicuous topographic forms but may often be recognized by the erratic bowlders on the surface. The best method of detecting them is undoubtedly from sections exposed in stream cuttings, where the peculiar characteristics of unsorted glacial débris may be recognized with little difficulty and the features distinguishing it from water-sorted and water-laid material may be made out. The till sheet is easily recognizable in many gravel sections about Summit Lake, on the broad, round-topped hills from Gakona Glacier to Delta River, and in the broader valleys, such as those of Eureka Creek, Valdez Creek, Maclaren River, and Susitna River. In the Summit Lake region the ground moraine rests unconformably on the tilted beds of the unconsolidated gravel and sand referred to the Tertiary, and in many places is only a few feet thick. Probably all the area in this region formerly occupied by ice was covered at one time by a veneer of till, much of which has since been removed by erosion.

A more noticeable form of glacial deposit is the moraine material deposited along the front and sides of the ice during times of relatively small movement in the margin. Many conspicuous examples of such moraines appear in this region. One of the best is on Maclaren River below the mouth of the west fork and in the valley to the west between Maclaren River and Little Clearwater Creek. The ice front faced the south and left a conspicuous terminal moraine several miles long extending over the ridge west of the river and across the valley that succeeds it to the next ridge beyond. This moraine has a height of 50 feet in places, but is only a part of a great mass of deposits of similar nature in the vicinity. Another good illustration of such morainal topography is furnished by the district about the head of Delta River in the vicinity of the Tangle Lakes.

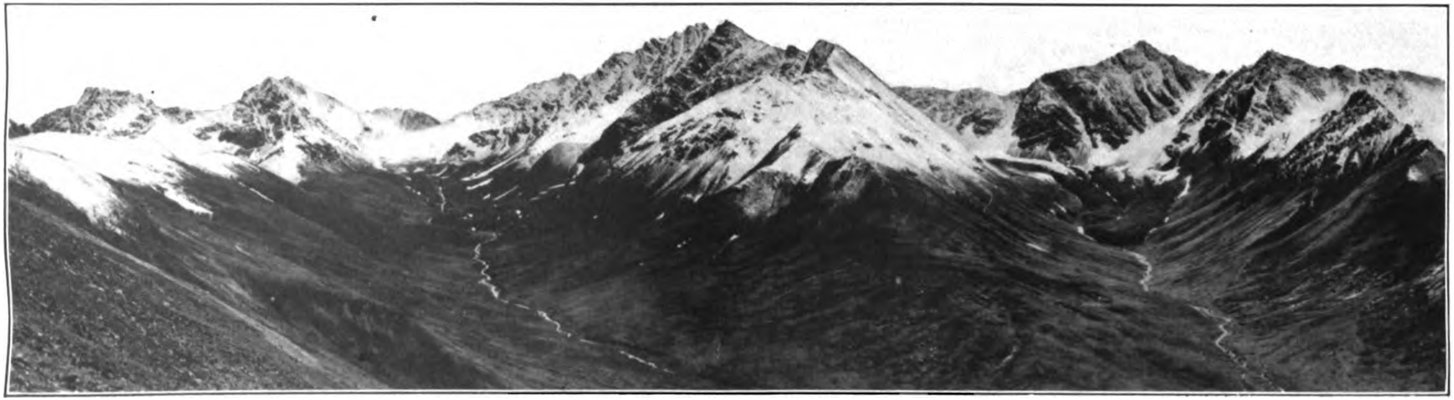
Practically all the present-day glaciers in this part of the Alaska Range have small terminal moraines, some of which show very distinctly the form and recent position of the ice front and the recession that has taken place. An excellent illustration is furnished by the glacier in which Eureka Creek and the east fork of Maclaren River head. Two concentric moraines several hundred yards apart cross the valley half a mile or more from the ice front and form dams which hold back the water in a number of small lakes. Terminal moraines of this kind rarely escape destruction for any great length of time unless they are situated at the side of the stream above the flood plain. They are nearly always undermined by water from the glacier and are carried away and deposited as stream gravels. Only in rare instances are their remnants found in the gravel-floored valleys of glacial streams, although it is evident that they must have once existed there, unless the former action of the glaciers was entirely different from what it is at present.

Lateral moraines border the present glaciers and appear as benches along the sides of valleys from which ice has long been absent. They are especially conspicuous in valleys with steep high walls, such as the upper part of Maclaren River and its west fork, and it is generally possible to find them in any of the smaller valleys. They mark positions at which the ice level on the valley walls was relatively stable for a time, and are much more apt to be preserved than terminal moraines of valley glaciers, inasmuch as they are away from the influence of the streams.

The southward extent of unmodified glacial deposits in the upper Susitna River region is not known, but it is highly probable that all the region under consideration has been covered by ice at one time or another; and it is therefore possible that the till sheet may also have covered the entire area. This, however, does not mean that the till is present everywhere in the area now, for part of the material that formed it may have been sorted and redeposited by streams since it was laid down by the ice. The lowlands extending west



A. BASALT MOUNTAINS ON THE SOUTH SIDE OF WINDY CREEK.



B. UPPER VALLEYS OF WHITE AND BIG RUSTY CREEKS.

from the south end of Gulkana Lake to Susitna River were not visited by the geologic party, and it was not learned whether the morainic topography such as that described on the upper part of Maclaren River and in the northern part of the Tangle Lakes district is developed there.

Another peculiar topographic feature either produced directly by glaciation or closely associated with it is described by S. R. Capps[1] under the name of rock glacier. Several excellent examples of loose-rock accumulations of this type were seen during the course of the field work. The best of these (Pls. V, *B*, and VI, *A*) is at the head of Big Rusty Creek, a tributary of White Creek, which, in turn, is a tributary of Valdez Creek. This mass of loose-rock material is more than a mile long and is fully 50 feet high at its lower end. It heads in two cirques from which glaciers formerly issued, and has the appearance of a glacier, except that it is made of rock fragments instead of ice and is narrower than most glaciers—even than those commonly found in valleys so comparatively small as this one. Deep depressions like those between a valley glacier and its confining walls intervene between it and the valley walls on either side, so that its close resemblance to a glacier in form at least is immediately evident to one who has had an opportunity to see both. No ice is visible in the sides or top of this particular example, but it shows the longitudinal markings described by Capps as characteristic of the much better developed rock glaciers in the Chitina Valley. Another rock glacier, not so well developed, however, as that on Rusty Creek, was found on the south side of the branch of Valdez Creek called Grogg Creek.

STREAM AND LAKE GRAVELS.

A detailed description of the present-day stream gravels in this region would not be of great interest even if the character of the field work and the opportunities for observation were such as to make close account possible. Gravels, important because of the gold contained in them are, however, described under "Economic geology" (pp. 58–62). Some of the stream gravels were produced by ordinary processes of erosion without the aid of glacial ice, but most of them in this region are reworked deposits of former and present glaciers. Practically all the larger streams, except Delta River, within the northern half of the mapped area, head in glaciers that are actively engaged in transporting rock waste from the high mountains to the valleys. All this material sooner or later is taken up by the streams, the fine and coarse fragments are separated, and the whole is redeposited and reworked time after time till no semblance of its original glacial character remains. The broad flood plains of the glacial streams are not fixed and unchangeable, but are built up or cut down as the channels shift from side to side across their surfaces.

---

[1] Capps, S. R., Rock glaciers in Alaska: Jour. Geology, vol. 18, No. 4, 1910, pp. 359–375.

The unconsolidated deposits of the southern or lowland area differ from those just described. They are believed to be closely connected in their origin with the more intense glaciation of the region and to have been deposited when the ice extended far southward from the Alaska Range. These gravels are seen in the high banks bordering Copper River, Gulkana River, and all the streams that have incised their channels in the lowland. No opportunities for detailed study of sections of the gravels were presented, but certain general statements can be made. The unconsolidated deposits exposed in the river banks consist of water-laid deposits associated with a smaller amount of glacial material. Glacial till and bowlder beds interbedded with the water-laid gravels are less evident in the northern than in the southern part of the area and very much less evident than in the part of the Copper River lowland south of the part now under consideration. As has been stated, the ground moraine overlies the gravel deposits on the northern border of the lowland, but similar beds were not observed interstratified with them. The point which it is desired to bring out will appear more clearly if a comparison is made with some of the localities studied by Mendenhall.[1]

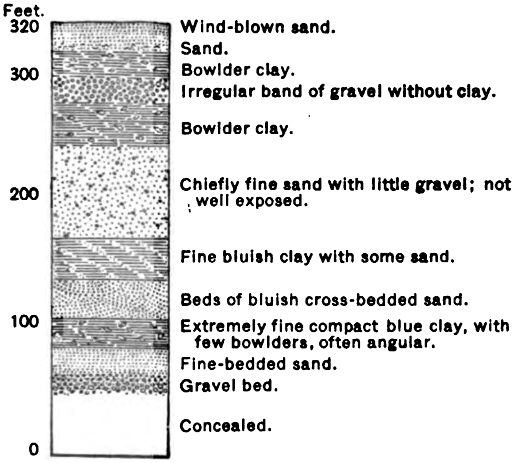

Feet.
320
300
200
100
0
Wind-blown sand.
Sand.
Bowlder clay.
Irregular band of gravel without clay.
Bowlder clay.
Chiefly fine sand with little gravel; not well exposed.
Fine bluish clay with some sand.
Beds of bluish cross-bedded sand.
Extremely fine compact blue clay, with few bowlders, often angular.
Fine-bedded sand.
Gravel bed.
Concealed.

FIGURE 2.—Section of Pleistocene on Klawasi River.

Three of Mendenhall's sections are of particular interest because they throw light on the manner in which the deposits were made and because they bring out differences already noted between the deposits in different parts of the lowland. The localities are all near Copper Center, the most distant being a little more than 20 miles south of Gulkana. Mendenhall describes them as follows:

> One and one-half miles above the mouth of the Klawasi, which flows into Copper River opposite and a short distance above Copper Center, is a section of 320 feet (fig. 2), of which all but the basal 40 feet are sufficiently well exposed for examination. * * * Above the 40 feet at the base, which are concealed, is a 10-foot bed of rounded gravel, over which are 20 feet of fine-bedded sands, underlying 20 feet of blue bowlder clay. The succeeding 100 feet con-

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 62 et seq.

> sists of interbedded fine clays and sands. Above this member are a bed of bowlder clay and some stratified pebble-bearing clays similar to those at Tonsina bridge. The top of the section is a wind-blown sand drift. This section reveals a succession of rapidly-deposited water-laid beds, with at least two short epochs of ice invasion represented by the sheets of till near the top and bottom of the bluff. The water-laid deposits are usually sands or gravels, and may well have accumulated just beyond an ice front as a sand or gravel plain. * * *
>
> On the north bank of the Klutina, about 6 miles above Copper Center, is a bluff 400 feet high, the beds of the upper 300 feet being fairly well exposed. The lower 100 feet of this exposure consists of compact, structureless, pebble-bearing clays, without lamination. The pebbles are well rounded, are sparingly distributed through the clays, and represent a variety of rock types. * * * Overlying it are about 85 feet of well-laminated beds entirely free from coarse material. They are believed to indicate lacustrine conditions. Above these is a bed of typical till 40 feet in thickness, full of striated and rounded bowlders. This is succeeded, in turn, by lenses of river cobbles overlain by more clays with embedded pebbles. The highest member of this section, as of most, is a bed of cobbles immediately under the peat and moss of the surface.

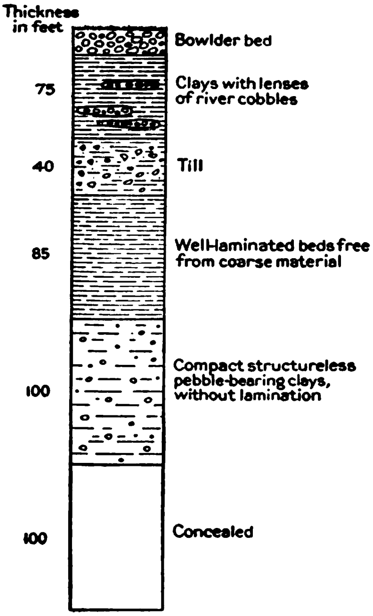

Thickness in feet
Bowlder bed
75
Clays with lenses of river cobbles
40
Till
85
Well-laminated beds free from coarse material
100
Compact structureless pebble-bearing clays, without lamination
100
Concealed

FIGURE 3.—Section of Pleistocene on Klutina River, 6 miles above Copper Center.

This section is illustrated in figure 3.

Mendenhall regards the pebble-bearing clays at the base as having been produced by rapid deposition in quiet water, and believes the pebbles to have been scattered through the clays by the agency of floating ice.

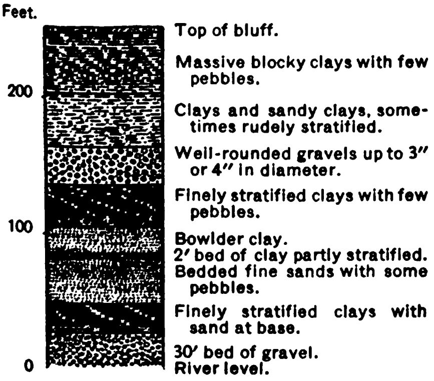

Feet.
200
100
0
Top of bluff.
Massive blocky clays with few pebbles.
Clays and sandy clays, sometimes rudely stratified.
Well-rounded gravels up to 3" or 4" in diameter.
Finely stratified clays with few pebbles.
Bowlder clay.
2' bed of clay partly stratified.
Bedded fine sands with some pebbles.
Finely stratified clays with sand at base.
30' bed of gravel.
River level.

FIGURE 4.—Section of Pleistocene on west bank of Copper River.

Just below the mouth of the Tazlina (fig. 4), in a bluff on the west side of the Copper, is an excellent exposure of 250 feet, which includes stratified sands and gravels, laminated clays, pebble clays, and one 10-foot bed of bowlder clay about 100 feet above the base of the section.

These sections are seen to be made up of fragmental material deposited under varying conditions. Some of it was laid down in quiet water, some in running water, and some was deposited by ice.

The changes followed one another abruptly, and any given condition was perhaps repeated a number of times in the same section, as, for example, the two ice advances indicated by the bowlder clay beds in the section shown in figure 2.

In comparing these sections with those exposed farther north on Copper River, Gulkana River, and elsewhere the important difference to be noticed is that the northern deposits are composed more largely of lake and stream gravels and, except on the surface, show less glacial material. The explanation probably lies in the fact that the sections of the gravels exposed along the streams from Gulkana northward are not so thick as in the region of Copper Center. The streams have not cut so deeply into the gravel and have not yet reached the lower till beds, if such beds are present. The river banks at Gulkana show distinctly stratified clays and gravel. The clays or silts are probably due to glacial erosion, but were deposited in quiet water. Mendenhall[1] makes the following comment:

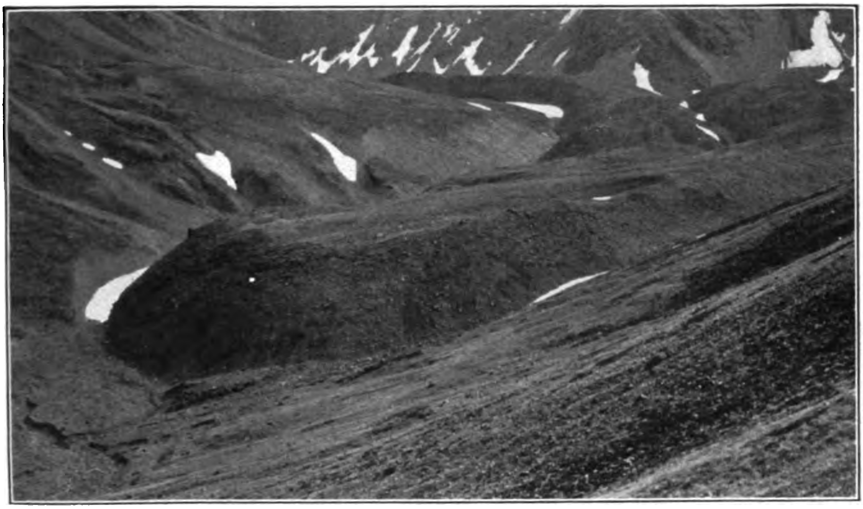
> The silt bluffs at the mouth of the Gakona, about 300 feet high, consist generally of fine, massive clays, through which pebbles are scattered. A few of the beds are laminated, and the general effect given at a distance is one of stratification in broad units.

These deposits are interpreted as the outwash gravels from a glacier front. It is probable that the whole of the Copper River basin has been invaded by ice that flowed into it from the mountain areas on every side. After the time of maximum extension the ice doubtless disappeared from the central region, but the high mountains continued to be a feeding ground of glaciers that moved down to the lowland and contributed an enormous quantity of rock waste to the streams produced by their own melting. This débris was spread out before the glacier front. Some of it came to rest in lakes or ponds and some was deposited by swiftly flowing streams. The retreat of the ice was not continuous, but was interrupted by advances that carried the margin out over the water-laid deposits and gave rise to the bowlder beds or till sheets interstratified with the gravels and clays. If this interpretation of the origin of these deposits is true it seems probable that the central part of the Copper River lowland will show the ground moraine only locally, for a large part of it must have been covered by the later outwash gravels or have been subjected to transportation and redeposition by streams.

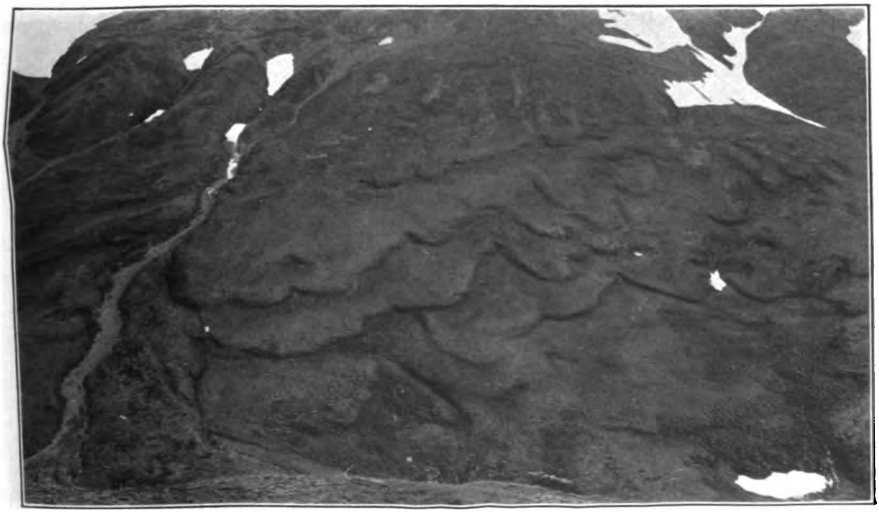
One of the forms assumed by surficial deposits not due to the agency of glacial ice or to deposition in water deserves special mention because of its fine development in parts of this region. This form, which is that taken under certain conditions by rock waste on the hill slopes, will for convenience of description be referred to here as "soil flows," inasmuch as no better name seems available, though

---

[1] Op. cit., p. 70.



A. ROCK GLACIER ON BIG RUSTY CREEK.



B. SOIL FLOWS AT HEAD OF VALDEZ CREEK.

the number in use is great. The illustration (Pl. VI, *B*) represents some "soil flows" at the head of Valdez Creek. They are produced by a gradual downward movement of the soil on hill slopes, and may be compared to the flow of a viscous substance, such as thick tar, on an inclined plane. The movement, considered with reference to the total distance traveled down a hill slope, is exceedingly slow, so that years might be required to show any notable advance, although progress at a particular time may perhaps be rapid. The parts of the lobes in the example shown in the illustration are several feet high and are covered with moss and grass. The tops of the flows have a distinct radial striation and are also covered with vegetation. The presence of water in the soil, perhaps to the point of saturation, is necessary for such movements, but it is believed by the writer that one of the important causes for the "flowing" of the soil in the manner shown arises from repeated freezing and thawing of the water contained in the loose rock waste, for it seems doubtful that the presence of water alone is sufficient to produce the movement. "Soil flows" of this kind are very common on hill slopes in the more northern parts of Alaska, but are not frequently seen in the Copper River basin. The distinct radial markings shown on the "soil flows" of Valdez Creek are not common in such flows, at least in the experience of the writer, although they are very general in loose material on steep bare slopes and in rock glaciers. Doubtless in all these forms they result in part from a downhill movement of the material.

STRUCTURE.

The structure of the Alaska Range is highly complicated, and it is scarcely possible to understand it until more accurate knowledge of the stratigraphy is gained. Increased knowledge of the region indicates, however, that faulting plays a far more important rôle in the structural relations of the different rock masses than at first sight appeared. The range itself is one of the dominant structural features of Alaska, represented further by the Pacific coast line, the great interior valley, and the Endicott Mountain range. It is believed to represent a zone of weakness and adjustment that dates back beyond the present range and may, perhaps, have been the site of older ranges that long since disappeared.

It is not to be expected that all parts of the Alaska Range will show identical structure, because the forces acting to produce deformation could scarcely have been of equal intensity or quality in all places, and because the rocks involved differ greatly. Brooks[1] describes the Alaska Range southwest of Mount McKinley as a broad synclinorium made up of closely folded rocks in which minor anticlines and synclines are recognizable. The succession of beds, however, on the inland slope of the mountains has been disturbed by extensive thrust faults. Mendenhall,[1] on the other hand, describes the range in the vicinity of Chistochina River as carved by erosional agents from a number of tilted fault blocks and shows that even on the southern or downthrow side the Tertiary beds dip gently away from the axis of the range and have a position relatively higher than their original one.

---

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 111.

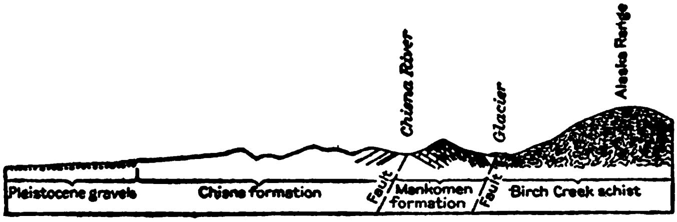


FIGURE 5.—Structure of the Alaska Range in the vicinity of Chistochina River.

These relations are better understood from the diagram (fig. 5), which is based on Mendenhall's description of the structure. The Mankomen formation abuts against the Birch Creek ("Tanana") schist on the north. The dip of the Mankomen is northward and increases in that direction so that it is greatest in the vicinity of the great fault between the Pennsylvanian slates and limestones and the schist. On the other hand, the underlying Chisna formation, which is separated from the Mankomen by a second great fault, dips to the south, and in places, as in the area about Gakona Glacier, is overlain by southward-dipping Tertiary sediments.

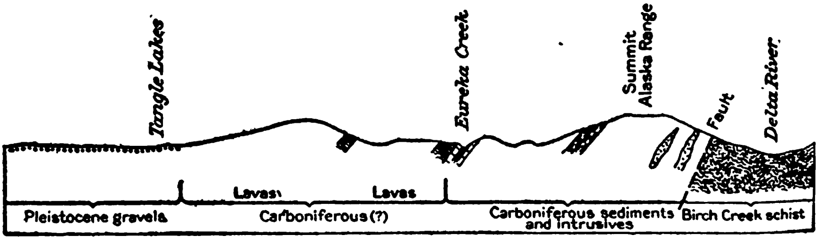


FIGURE 6.—Structure of the Alaska Range in the vicinity of Delta River.

In the region just west of Delta River still other conditions prevail which more nearly resemble those in the Chistochina district than in the McKinley region. The structure is shown diagrammatically in figure 6, which indicates that the high, axial part of the range is made up of the Birch Creek schist on the north, separated by the great fault from the Carboniferous rocks on the south. These

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 82–84.

Carboniferous beds, which are made up of intercalated sedimentary and igneous rocks, dip to the south beneath the lava flows of the ridge south of Eureka Creek. The lava flows are represented as folded into a broad syncline, but it is not intended to imply that the schists of the Tangle Lake district are to be correlated with the beds north of the syncline, although this may possibly be true. Diorite intrusions are common in the vicinity of the great fault, and, as suggested by Mendenhall, probably account for several of the high peaks, such as Mount Hayes, Cathedral Mountain, and Mount Kimball, in the axis of the range.

The structure of the Alaska Range at the head of Susitna River is more complicated than it is near Delta Pass and is not well enough understood to warrant the drawing of a section to represent it. In the vicinity of Valdez Creek the lava flows exposed south of Windy Creek appear to dip beneath the Triassic sediments, and these, in turn, to pass beneath the schists and the great diorite mass between Valdez and Bowlder creeks, but it has already been pointed out that a fault may exist between the slates and schists. The region between Valdez Creek and Mount Hayes is occupied, so far as known, by slates or schists and diorite, and it would seem, from the appearance of the lower hills on the flanks of Mount Hayes and Cathedral Mountain, that diorite forms a large part of the mass. Photographs of Mount Hayes show the beds at the base of the mountain dipping toward the north, but it is unsafe to base generalizations concerning structure on the meager evidence obtainable regarding this vicinity.

In summarizing these conclusions in respect to structure, it may be said that in the Alaska Range in the vicinity of Delta Pass and eastward toward Mentasta Pass a belt of Carboniferous and post-Carboniferous sedimentary and igneous rocks lies between schists on the north that are much older and others on the south that may be older. This belt of sedimentary and igneous rocks can not be interpreted as a simple synclinorium because the structure is complicated by profound faulting that has brought about relationships between the several formations entirely different from those that would have resulted from folding alone.

HISTORICAL GEOLOGY.

EARLY GEOLOGIC HISTORY.

In this section it is intended to outline in a very general way the most important geologic events indicated by the rocks of the region. The earlier events are obscure, but as the present is neared it is possible to recognize more and more distinctly the changes that took place.

The first geologic records found in this region are contained in the Birch Creek ("Tanana") schist, a series of sedimentary beds considered by Brooks to have been deposited in pre-Ordovician time,[1] which forms the north side of the Alaska Range from Nenana River to Mentasta Pass. They are intruded by igneous rocks, and because of the high degree of metamorphism which both sediments and intrusives show it is inferred that they were extensively folded, elevated above the sea, and subjected to erosion before the next younger sediments were deposited on them.

If the schists of very doubtful age near Myer's road house and at the Tangle Lakes be neglected, the next period of deposition concerning which knowledge exists took place in Carboniferous time and is represented by the rocks which are correlated with the Chisna formation. These were laid down in a time of volcanic activity, as is proved by the tuff beds and lava flows intercalated with the quartzites, slates, and other sediments of this epoch. The Carboniferous sea was an extended one, but changes took place in the relation of sea to land from time to time, and deposition in this region was not continuous. The best evidence at hand seems to indicate that there was an interruption in sedimentation between the part of Carboniferous time represented by the Chisna formation and that represented by the Mankomen formation of the Chistochina district. Probably the older Carboniferous formation was elevated above sea level with little deformation and was subjected to a period of erosion before the later sediments were laid down. Depression below the sea was followed by deposition of the latest Carboniferous rocks, the Mankomen formation. The Mankomen was also a period of volcanic activity, the outbursts being most pronounced while the lower beds were being deposited and diminishing toward the close of the period, for the upper beds in the Chistochina district appear to be free from volcanic deposits.

There is doubt concerning the time in which the great outpouring of lavas south of Eureka Creek and Windy Creek took place, but it is assumed tentatively that it was later than the Mankomen epoch. It is known definitely that the upper Carboniferous limestone at the head of White River, which is equivalent in age to the Mankomen formation of the Chistochina district, is succeeded by a great thickness of basaltic lavas and tuffs older than the Tertiary lavas which make up most of the Wrangell Mountain mass. Furthermore, the Nikolai greenstone of the Chitina Valley, consisting of at least 4,000 feet of lava flows, underlies the massive Chitistone limestone (Upper Triassic), and although it has not been proved that the Nikolai greenstone represents the upper part of the lava flows overlying the

---

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 59.

Carboniferous limestone of White River there is a presumption that this is true.

The lava flows of Eureka and Windy creeks, in the absence of proof to the contrary, are thought to occupy a similar position relative to the Carboniferous and the Upper Triassic sediments and to have been erupted at the end of the Carboniferous period or during the early or middle part of the Triassic. Some of the lavas may have been poured out under water, for they are interstratified with tuff beds and slates, but many amygdaloidal flows among them suggest surface conditions. In any event the absence of Lower and Middle Triassic sediments indicates that the region was probably a land mass during part of that time. In Upper Triassic time the land was again submerged, and limestones, slates, and associated tuffaceous sediments were deposited. No conclusive evidence is at hand to show that any other Mesozoic sediments are present in the region under discussion, although sedimentary Jurassic rocks are widely distributed in the neighboring Talkeetna Mountains. The Jurassic period, however, was one of widespread intrusion throughout the Alaska Range and is represented by the great masses of diorite injected into the sedimentary deposits of this region.

It appears that after the Triassic beds were deposited the region became a land mass and continued as such through late Mesozoic and early Tertiary time. It was deformed to some extent, although the folding does not appear to have been great, and other changes took place that are indicated by the difference in metamorphism between the Triassic and the younger rocks. Erosion finally reduced the area to a lowland on which the fresh-water sediments of upper Eocene (Kenai) time were laid down.

LATER GEOLOGIC HISTORY.

TOPOGRAPHIC DEVELOPMENT.

Deposition of the fresh-water Tertiary sediments may appropriately be considered as beginning the later geologic history of this region. The Tertiary sediments were laid down in fresh inland waters and although widespread probably never formed a continuous deposit over all the region where their isolated masses now occur. They were deposited in an area of low or moderate relief, but were closely folded in the mountain-building movements that originated the present Alaska Range. These movements began soon after the Tertiary sediments were deposited and slowly raised the mountain area above the bordering low country, giving the streams an opportunity to attack and dissect it. The present drainage lines were established, but the topographic forms have since been greatly modified by glaciation. Profound faulting accompanied the folding, as is shown by the attitude of the Chisna formation to the Birch Creek schist and to the Mankomen formation.

The origin of the Alaska Range and its relation to the Copper River plateau has been discussed by Mendenhall,[1] who regards the high mountains as having been carved from elevated fault blocks and the lowland as a sunken area separated from the Alaska Range on the north by a great fault and from the Chugach Mountains on the south by a great fault or a flexure (fig. 7). Less evidence in support of this proposition was seen in the region between Gulkana River and Susitna River than was found by Mendenhall in the region east of Gulkana River, but it is the most plausible explanation yet offered and can not be discarded unless it is disproved or a more satisfactory one proposed. The questions involved are not local ones peculiar to this area, but are concerned with the later history of all southern Alaska, and will probably not be fully answered till much more extended work is done.

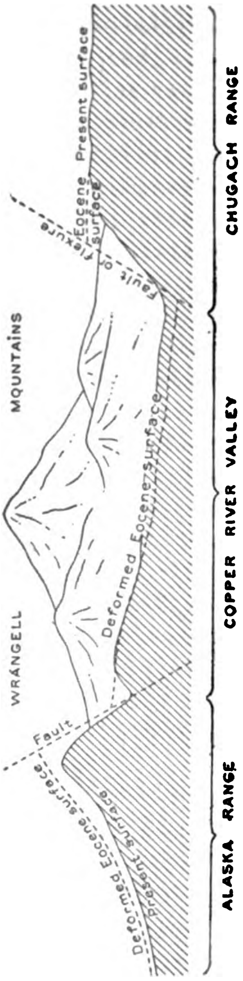


FIGURE 7.—Relations of present and Eocene land surfaces in the Copper River valley.

A problem of special interest is that concerned with the origin of Delta Pass through the Alaska Range and the similar pass to the west through which Nenana River flows. Delta River receives most of its water from the glaciers that feed Eureka Creek, from the Tangle Lakes, and from Gulkana Glacier, all south of the axis of the range, but it flows northward through the range and joins the Tanana instead of becoming part of the Pacific drainage, as would be expected. The same glaciers that feed Phelan and Eureka creeks also contribute water to Gulkana and Maclaren rivers. Almost the same conditions are true of Nenana River, which rises south of the Alaska Range, flows westward through the southern foothills for a considerable distance, and then cuts directly through it. Three explanations suggest themselves for this peculiar drainage feature—the Delta may be older than the Alaska Range and may have deepened its channel as fast as the mountains rose; it may have cut its way through from the north side by headward erosion; or it may owe its peculiar position partly to conditions that arose during glacial time. A low preglacial saddle, such as may probably have existed where the Delta Valley now cuts the range, would almost certainly have been taken advantage of by the ice as a northern outlet from the area south of the pass. It seems to be well established that the accumulation of ice on the south side of the range was greater than that on the north, and it is believed that some of this ice, instead of moving south, moved north through the gap and, partly by glacial erosion and partly by damming back the water on the south, enabled the Delta to establish itself there.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 82–88.

It is difficult to see how the river could have maintained its course across the Alaska Range while the latter was being elevated unless some special cause intervened, since it appears as if opportunity for drainage to the south was as good, if not better, than to the north. The same objection applies to headward erosion. The distance to the sea is less and the grade is greater on the south side than on the north side of the range.

The problem that the Delta presents is similar to that raised by Copper River in its course through the Chugach Mountains and it is not at all unlikely that the solution of one will contribute to the solution of the other.

GLACIATION.

Glaciation was one of the important agents in giving the mountains of the Alaska Range the form they have to-day. No doubt the drainage system was well established before the ice invasion took place, but the valleys owe their present form in large measure to ice erosion and to the deposition of rock waste that accompanied it. The present glaciers afford little idea of the former ice sheet in this region and in determining its extent dependence must be placed on other features, such as glacial deposits and striæ.

Much has already been said about the work of ice, especially in regard to the material laid down by it and the part such deposits have in the topography. The till sheets in the Pleistocene deposits of the Copper River lowland testify that the whole interior basin of Copper River, bounded by the Alaska Range, the Wrangell, the Chugach, and the Talkeetna mountains, was at one time or another buried by ice. Ice streams are known to have moved from all these high mountain areas to the lower country. The Alaska Range was an important place of ice accumulation; not only was the high central part of the range a gathering place for snow and ice, but the lower range to the south also contributed. Most of the ice moved southward, directed in part by the larger stream courses, such as Susitna, Maclaren, and Gulkana rivers, but it spread out as it left the confining valleys and probably covered many or possibly all of the low hills on the borders of the lowland. The round-topped hills near

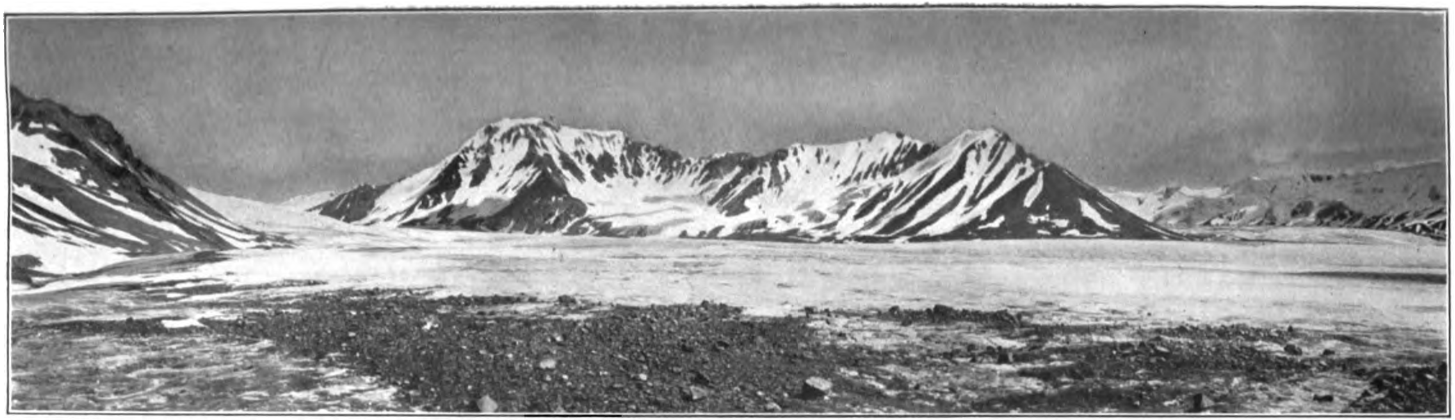
Myer's roadhouse are glaciated, as would be expected since they lie in the path of one of the larger ice streams which moved down the valley of Gulkana Lake from the north. Hills of similar form west of Gulkana River may also have been covered.

It is fairly certain, however, that in an area including much of Phelan and Eureka creeks and part of Delta River the ice movement was north through Delta Pass instead of south, for the basalt mountains west of Summit Lake obstructed in considerable degree movement in that direction. Another reason why the movements here should have been northward is that the evidence, as previously stated, points to a much greater accumulation of ice on the south side of the axis of the range than on the north side. The tendency of the ice would have been to move in the direction of least resistance, and any large mass in the area south of Delta Pass to the basalt mountains would have sought relief from pressure by movement northward through the pass as well as southward through the few available gaps unless it were opposed by some larger mass of ice in that direction. This small area shows evidence of severe glaciation throughout its extent. The rock, where exposed, in such places as the low basalt hills bordering Eureka Creek on the south or on the lower slopes of the basalt ridge south of Garrett's cabin, is grooved and worn by moving ice.

It is impossible to say how thick the ice covering was, but it must have been measured in hundreds and perhaps thousands of feet. The mountain sides east and north of the upper branches of Susitna River show that where confined in the valleys it filled them to a height more than 2,000 feet above the present streams. The ice crossed the broad divide between Bowlder and Valdez creeks from the north at an elevation more than 1,500 feet above Susitna Valley, and it is probable that only the tops of the neighboring mountains were above it.

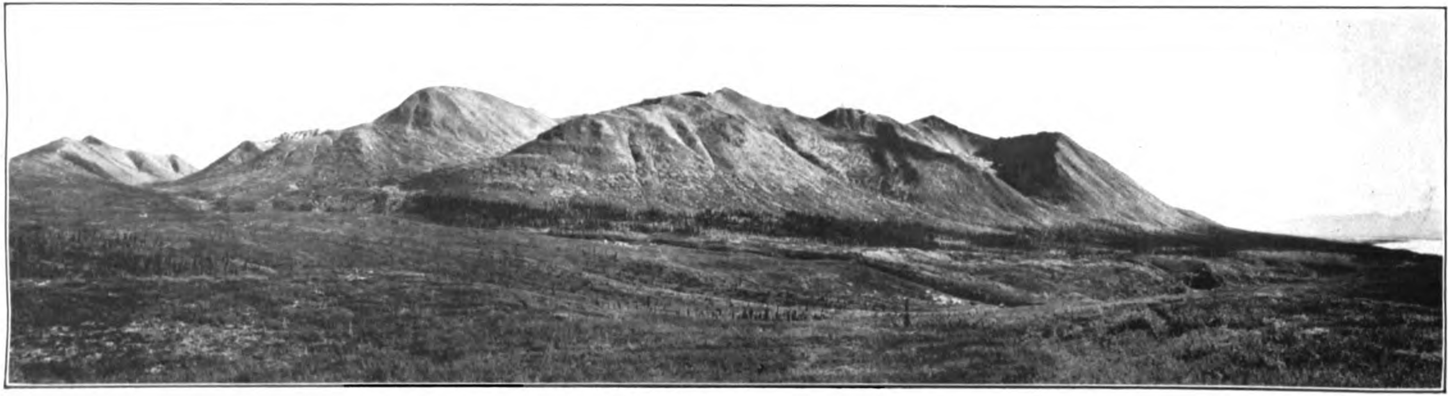
The east-west ridge north of West Fork of Gulkana River would present a serious barrier to ice moving from the north, because it stands from 1,000 to 3,000 feet above the lowland on that side and it seems doubtful whether it would have been overridden by glaciers from the north. These hills, however, may themselves have been a gathering ground for snow and ice. Such an obstruction, furthermore, would not have prevented the glaciation of the country south of the ridge for the Wrangell and Talkeetna mountains sent out streams of ice whose movements were unopposed by any such barrier.

The topographic map (Pl. I, in pocket) shows how numerous the present-day glaciers are in the high part of the mountain area and what an important element they are in the drainage. All the streams of consequence derive a large part of their water from melting glacier ice and flow through valleys floored with glacial gravels.



A. VIEW ACROSS GULKANA GLACIER FROM WEST SIDE.

Shows a type of Alaska range topography.



B. VIEW SHOWING THE TOPOGRAPHY OF LOWER VALDEZ CREEK VALLEY FROM THE NORTH.

The most conspicuous of these glaciers are Gulkana Glacier (Pl. VII, *A*), the glacier in which Eureka Creek and East Fork of Maclaren River head, Maclaren Glacier, and the two large glaciers at the head of Susitna River. The last two are much larger than any others in this region. They are fed by the snow fields in the high rugged country south of Mount Hayes and Cathedral Mountain and are the principal sources of the Susitna, although the glaciers to the east also contribute much water. The westernmost of the two large glaciers is about 25 miles long and more than 1½ miles wide throughout its whole length. The eastern glacier is about 2 miles wide, but is not so long as the first. Maclaren River Glacier is much smaller than either of these, being a little more than 10 miles long and not more than a mile wide at its lower end. Gulkana Glacier and Canwell Glacier, near the northwest corner of the area mapped (Pl. I, in pocket), are remarkable, as has been stated, in that they contribute water to both Bering Sea and Pacific Ocean drainage.

Most of these glaciers appear to be retreating. Their surfaces are smooth, they end in smooth slopes rather than ice cliffs, and most of them show by the position of terminal moraines that they have receded considerably in recent time.

Glaciation is the last of the great events that took place in the geologic history of this region, and it is still in progress. Its effects are for the most part concerned with topography, and are seen in the form of the mountains, the slopes of the valleys, the moraines, and the broad outwash plains of glacial gravel. These features have all been modified to some extent by postglacial erosion, but they are nevertheless the chief elements of the present-day topography.

ECONOMIC GEOLOGY.

GOLD.

VALDEZ CREEK DISTRICT.

HISTORY AND PRODUCTION.

The history of mining in the region between Gulkana and Susitna rivers is concerned chiefly with Valdez Creek. A few of the prospectors who came into the Chistochina River region in 1898 found their way to Delta River and its western headwater tributaries, but they were unsuccessful in their search for placer gold and did not make any important discoveries.

Gold was discovered on Valdez Creek on August 15, 1903, by a party including Peter Monahan, J. S. Smith, J. M. Johnson, and J. C. Clarkson, who, with several others, left Valdez with dog teams in February of that year and crossed the Valdez Glacier to Klutina

River. They made their way to Susitna River by following Klutina River, St. Ann River, and Tyone Creek, crossing Klutina, Hudson, and Taslina lakes and the Susitna Lakes on the ice. Their first base camp was near the "stick houses" at the mouth of Tyone Creek, from which they began their search for gold by prospecting the streams tributary to Susitna River below Tyone Creek. They found fine gold on the bars of a stream which they called Goose Creek (a creek rising in the Talkeetna Mountains and corresponding to the one named Oshetna River on later maps), but not satisfied with the results of their labor they left this region for the upper Susitna. At Maclaren River the company separated into two parties, one of which ascended that stream, and the other, known as the Monahan party and including the men named, made its way up the Susitna, prospecting the different tributary creeks as it went. Gold was found on Butte Creek and on its tributaries, Gold and Wickersham creeks, but not in sufficient amount to satisfy the prospectors. They then crossed Susitna River from the west side to a stream which the natives called Galina, and made their first important gold discovery below the mouth of a narrow rock-walled canyon on Discovery Bar. They renamed the stream Valdez Creek and spent the few remaining days of the season before going back to Valdez in getting out a "grubstake."

The following spring they returned with supplies and equipment, coming in over the Valdez Glacier as in the previous year, and accompanied by other prospectors anxious to secure claims on Valdez Creek or to discover gold in new placer districts.

The rich gravels of the old canyon on "No. 2 above" and the "Tammany bench" claims were found in the fall of 1904 in an attempt to learn why the gold content of the creek gravels suddenly fell at a particular point in ascending the stream. Panning in the talus on the north side of the creek led to the source of the gold in the earlier concentration of the old canyon, and the most important discovery of the district was made. Not much work was done in the old canyon, however, till the following year. In the fall of 1904 the miners of Valdez Creek, under guidance of a native, went out over the Gulkana trail for the first time, and the Valdez Glacier route was given up.

The value of the total gold production of Valdez Creek, including that of the summer of 1910, is estimated to be about $275,000. There has been a falling off for the last two years, owing to the decrease in yield of the creek gravels, but the reduction will probably not be much greater for some time to come, for there remains gold-bearing gravel that has not been touched, and the prospects for an increased yield from other creeks are good.

SOURCE OF THE GOLD.

A number of conditions make it possible to trace the gold of Valdez Creek to its principal bedrock source and to be fairly confident that the source is within an area of comparatively narrow boundaries. The most important of these is the distribution of gold in the creek gravels. Prospecting has shown that the tributaries of Valdez Creek that flow into it from the hills on the north yield practically no gold. On the other hand, tributaries such as Timberline Creek, White Creek, and Lucky Gulch, that rise in the mountains to the south, carry important gold-bearing gravels. The north side of Valdez Creek valley is a region of schist and altered intrusive diorite; the mountains on the south side of the valley are slates, locally schistose, intruded by diorite and related porphyritic rock. Intrusives are much less abundant than on the north side and are also less altered; in fact, many of them are practically unaltered. The slates therefore appear to be the rocks in which the principal mineralization took place. Prospecting has not yet shown the presence of gold in commercial quantities in the tributary streams east of Lucky Gulch or west of Rusty Creek, although fair prospects have been found on Timberline Creek. It should be kept in mind, however, that all the gravels of these southern tributaries contain small amounts of gold.

The hill between White Creek and Lucky Gulch, known locally as Gold Hill, is of special interest in connection with the bedrock source of gold. This hill is composed of slates, dipping north and intruded in places by a light-colored fine-grained igneous rock. The decomposed material on the hill slope yields fine gold on panning, as a result of which the gold has been traced to sources in bedrock at several places that have been staked as lode claims. None of these places have been opened up in a way to give satisfactory exposures of the gold-bearing rocks, but they show that some of the gold is associated with iron-stained siliceous veins containing pyrite, sphalerite, and galena. The decomposed material from these veins in places yields as much as $1 in fine gold to the pan. In nearly all the exposures examined it was found that the gold-bearing rocks were associated with fine-grained light-colored siliceous intrusives, whose presence leads to the belief that they are a factor in the origin of the gold. Large quartz veins containing scattered crystals of pyrite, but without visible free gold were seen in several places on Gold Hill, and in one locality veins of calcite associated with a little quartz and masses of fine, scaly biotite were found.

The placer gold from Lucky Gulch is of interest in this connection. It is remarkably coarse and contains many large nuggets, some of which are smooth but most of which are rough, with spines and protuberances. Sugary quartz is of common occurrence in the gold. It appears certain from the character of the nuggets and the narrow gulch in which they lie that the gold has traveled but a short distance from its source in the slates. Gold Hill is without much doubt one of the local centers of mineralization, but there is no reason to believe that there may not be other centers in the district. In fact it seems that there may be a nearer source than Gold Hill for some of the placer gold on the lower part of Valdez Creek.

The gold in the creek gravels is a concentration from the product of weathering like that on the slopes of Gold Hill. Some of it is a reconcentration from previous concentration in the gravel. The gold-bearing gravels of Valdez Creek below the Monahan Tunnel are of this kind. They derive their gold in large part from previous deposits in the old canyon. When the canyon of the present stream was being cut down through the old gravel-filled canyon formerly occupied by Valdez Creek the old gravels were reworked by the stream and their gold content was reconcentrated in the form they had when mining began there.

There are points of similarity between the occurrence of gold on Valdez Creek and in the Chistochina district. From the distribution of gold in the gravel Mendenhall[1] reached the conclusion that the placer gold of Miller Gulch, Slate Creek, and Chisna River is derived from an area of local metamorphism within the shales of the Mankomen formation. The mineralization, moreover, is restricted to an area of metamorphosed rocks which forms only a small part of the Mankomen formation as he mapped it. The slates are cut by light-colored granular intrusives, but the amount of these intrusives is much less than on Valdez Creek. The two districts resemble each other in that both are characterized by slightly altered slates intruded by granular igneous rocks.

LODE DEPOSITS.

Little attention has been given to the search for gold lodes in the Valdez Creek district and only a slight amount of work has been done to the present time (1910) toward proving the value of such gold-bearing veins as have been found. No gold has been produced from this source.

Two or three prospects on the north slope of Gold Hill were examined and some of the loose, decomposed vein material was panned, proving the presence of gold in each instance. At the Yellowhorn claim a small open cut had been made in loose talus material consisting of decomposed slate or schist and rusty quartz. No bedrock was in sight but the cut was partly filled with loose material that had slid down into it. Two pans of the waste material from the dump yielded about 10 or 15 cents worth of very fine gold. Much better pans have been obtained from this place.

---

[1] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 114.

The discovery ledge of the Accident claim is a small exposure of decomposed slates and siliceous fine-grained intrusive rock. The igneous rock is light gray in color and contains considerable pyrite. There is also some rusty vein quartz containing sphalerite and galena. Fine gold is present in the decomposed vein matter. About 300 or 400 feet above the Accident ledge and in the same steep gulch a little stream of water runs down over angular wash made up of slate and rusty quartz. A rocker had been set up at this point and very good prospects were obtained from the gravel. The fine-grained intrusive rock was exposed in the gulch just below it.

These prospects have not yet been shown to be of commercial value, but they are of importance in indicating how the gold occurs and offer encouragement for further search.

PLACER DEPOSITS.

DISTRIBUTION.

Most of the placer gold produced in the Valdez Creek district has been taken from a few claims at the western end of Valdez Creek just above the place where the canyon opens out into the flats of Susitna River, and from Lucky Gulch. It is probable that the gravels of Valdez Creek from the canyon to Roosevelt Creek contain a large quantity of gold, although the concentration may not be sufficient to make them of commercial importance with the methods of mining in use on the creek. The difficulties arising from the low grade of the creek, the depth of the ground, and the large amount of water have prevented careful prospecting to this time.

The three principal tributaries that join Valdez Creek from the south, Roosevelt, White, and Timberline creeks, have not contributed any considerable amount of gold to the total output. White Creek and its largest branch, Rusty Creek, have received more attention than either Roosevelt or Timberline Creek, and this attention appears to be justified by the results of prospecting on Rusty Creek during the last year.

The streams heading in the Alaska Range east of Valdez Creek have received some attention from prospectors, with the result that practically all of them are known to carry small amounts of gold, yet not enough to encourage mining except on Eureka and Windy creeks and near Delta River. A few men were at work on these two streams in 1910.

VALDEZ CREEK PROPER.

Geology.—Valdez Creek is approximately 14 miles long. It flows almost directly west from its source for 10 miles over the gravel floor of a broad, glaciated valley, then enters a canyon about 3 miles long, and finally emerges on the Susitna lowlands. The part above the mouth of Roosevelt Creek is about equal in length to Roosevelt Creek and carries approximately the same amount of water. Valdez Creek has a fall of 1,000 feet in the first 10 miles above the western end of the canyon, or an average fall of 100 feet per mile, but since the grade of the creek is 175 feet per mile through the canyon, the grade above the latter is slightly less than 53 feet.

The mountains about Valdez Creek rise more than 6,000 feet above sea level, or more than 3,000 feet above Susitna River. At the head of the creek they are made up of schist and slate on the south side and altered diorite on the north, but from Roosevelt Creek westward they consist of slate with diorite intrusives on the south side and schist with altered diorite intrusives on the north. The rocks exposed in the canyon are slates, intruded by dikes and sills of fine-grained diorite, which is porphyritic in places.

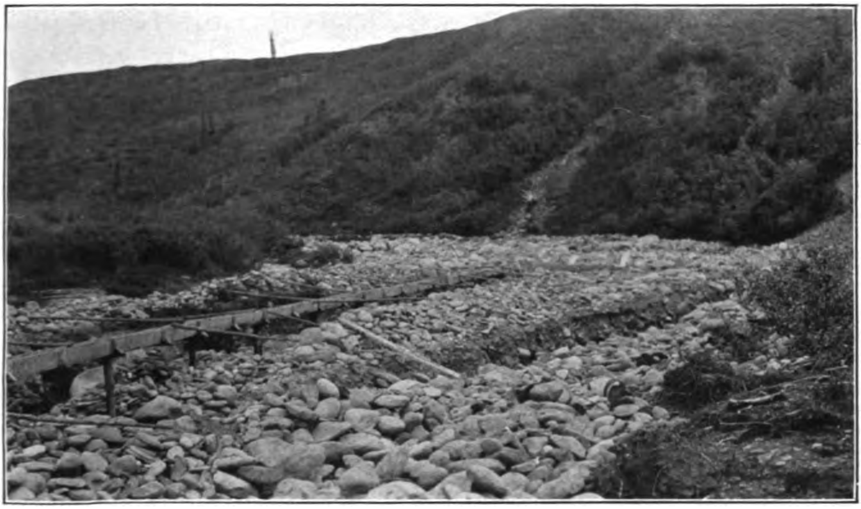
The valley is much glaciated, and in the lower broader part has a conspicuous morainal topography characterized by rounded knolls and swampy depressions. This is its character on both sides of the canyon where the valley begins to open out into that of Susitna River. The unconsolidated glacial deposits are spread over an uneven rock floor (Pl. VII, *B*, p. 52), which, though it doubtless owes its form in part to ice action, had a drainage system developed on it before the glacial gravels were laid down and the present channel of Valdez Creek was formed.

Valdez Creek has cut its canyon through the overlying gravels into the slates beneath to a depth of over 175 feet, and in so doing has intersected an older gravel-filled canyon whose bottom is 60 feet higher than the present creek level. The depth of the new canyon is greatest below the falls, a short distance downstream from the old canyon, at a point where the overlying gravels are shallow and almost the entire cut is in slates. Above and below, the depth of the canyon decreases.

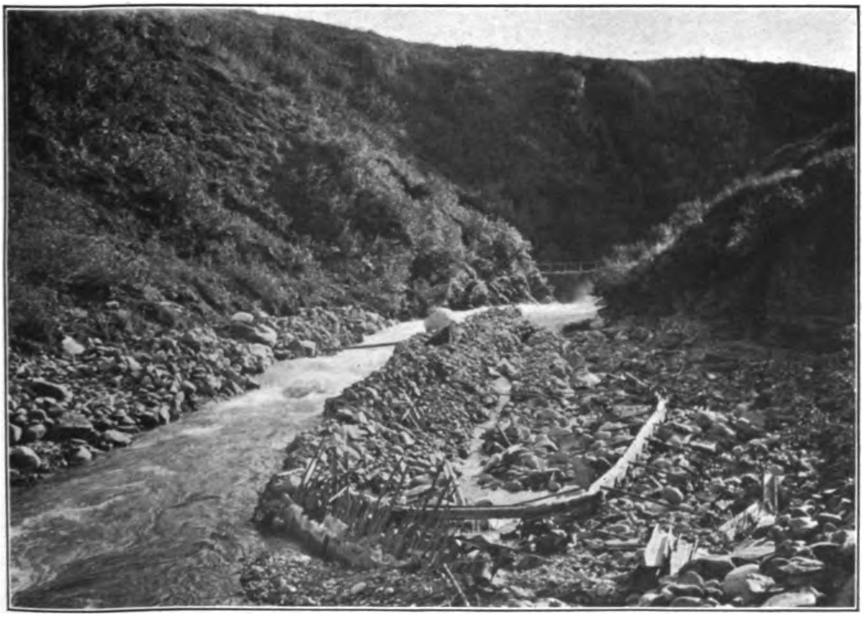
Mining development.—Mining development on Valdez Creek has been concentrated on four or five creek claims and two bench claims. The creek claims are Discovery, No. 1 below, No. 2 below, No. 2 above, and No. 3 above; the bench claims are Tammany bench and the claim adjoining No. 1 below on the south. Their location is shown in figure 8.

Discovery, No. 1 below, and the lower half of No. 2 above were the richest of the creek claims, but none of them have equaled in value the Tammany bench claim. The first claim above Discovery includes the narrowest and deepest part of the canyon, where the stream is confined between perpendicular slate walls, and no mining is carried on.

Creek gravels.—It is unnecessary to describe the gravel deposits of each creek claim in detail, because the variation in character is not



A. BOWLDERS FROM STREAM GRAVEL ON VALDEZ CREEK.



B. WING DAM IN CANYON ON CREEK CLAIM ADJOINING THE "TAMMANY BENCH," VALDEZ CREEK.

great. In general the gravels range in thickness from 3 to 8 feet on the three most productive claims and consist of slate, schist, and diorite, with which is associated a small amount of light-colored porphyritic intrusives and dark basic and tuffaceous material. An important and unfortunate characteristic of the gravel is its large content of bowlders (Pl. VIII, *A*).

At the upper end of claim No. 3 above, the gravel deposit reaches a thickness of 10 to 12 feet. The upper 6 feet contains many diorite bowlders and overlies finer gravel consisting of slate and diorite cobbles. Such a bowlder bed might indicate either a change in glacial conditions or simply a concentration of bowlders from deposits whose finer material has been carried away, but the absence of large bowlders in the underlying material suggests some different condition of deposition.

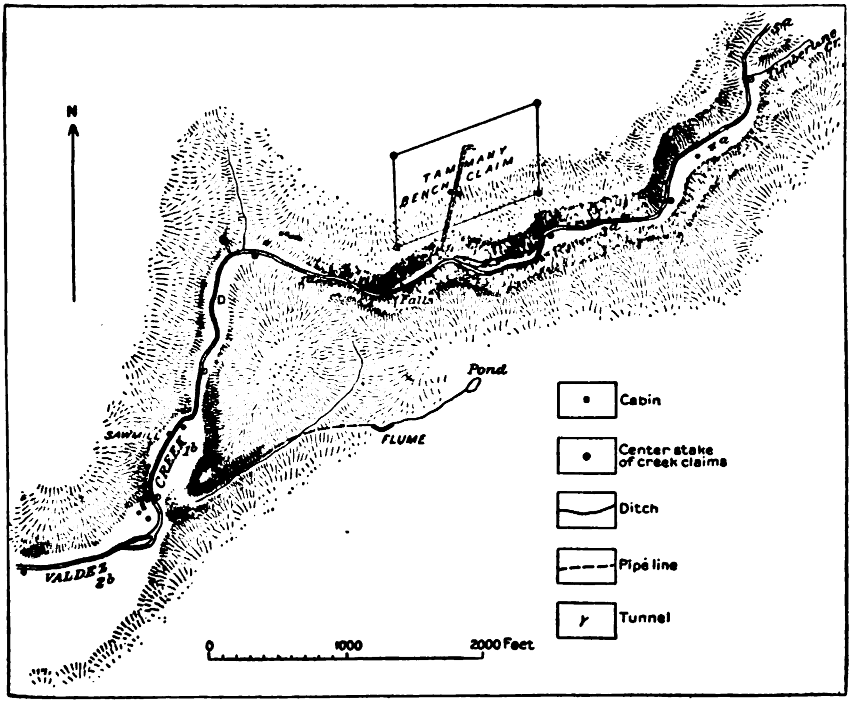


FIGURE 8.—Sketch map of part of Valdez Creek, showing location of producing claims.

Much the larger proportion of the bowlders are diorite. They reach diameters of 5 or 6 feet and are a source of much expense to the miners, for they can be moved only at great expense and then only for short distances. It is customary when possible to undermine them on one side and cause them to roll over, thus permitting the gravel beneath to be taken away.

Gold from the creek claims shows variation in its form and appearance. Some of it is flat and well worn, but other specimens are rough and show little effects of wear. Gold from the claims above the Monahan tunnel is finer and less worn than that below, but a small proportion of smooth flat gold is present. The decrease in coarseness is more marked downstream from the tunnel than in the opposite direction, so that there seems to be no doubt that the old canyon gravels are responsible for the richness of Valdez Creek downstream from claim No. 2 above. The gold is associated with a large amount of red garnet or "ruby sand," and a little magnetite or "black sand." Magnetite is less abundant than might be expected from the quantity of igneous material in the gravel. An idea of the coarseness of the gold on claim No. 1 below may be gained from the statement that the largest piece found there in 1910 was worth $1.75 and the next largest $1.25.

The richest claim on the creek was Discovery claim, but the richest spot was on claim No. 1 below, a short distance downstream from the sawmill dam. A little more than one-third of the total gold production of Valdez Creek from 1903 to 1910 came from the creek claims, but so much of the rich ground has been mined out in that time that a falling off in production has taken place.

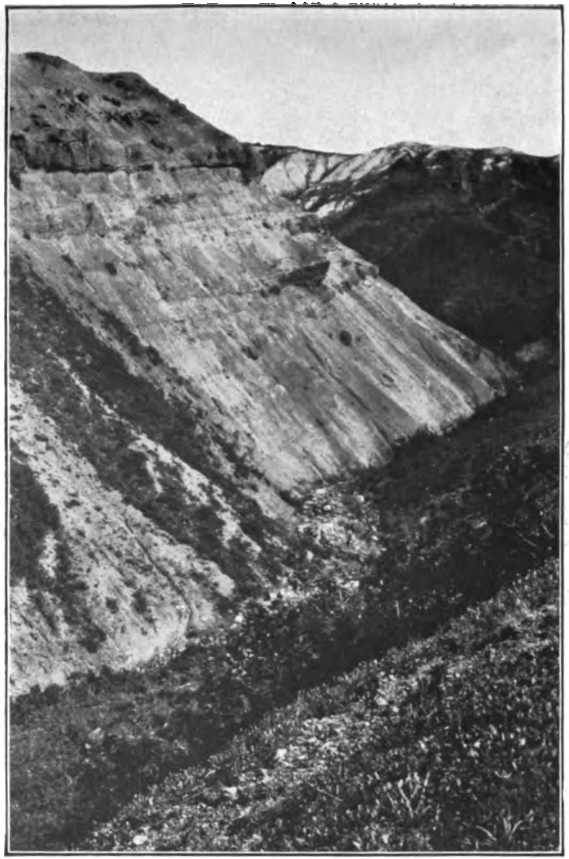
All the work on the claims above No. 2 below has been done with pick and shovel. The creek water is diverted by wing dams (Pl. VIII, *B*) or ditches, and the gravel is shoveled into the sluice boxes without the use of special mining appliances. Hydraulic mining was conducted on claim No. 2 below in 1909, and a Ruble elevator was used in disposing of the cobbles and bowlders; but the results were probably unsatisfactory, for the work was not continued in 1910.

Bench gravels.—Tammany bench and the claim adjoining No. 1 below on the southeast are the only bench claims on the creek that have been much developed.

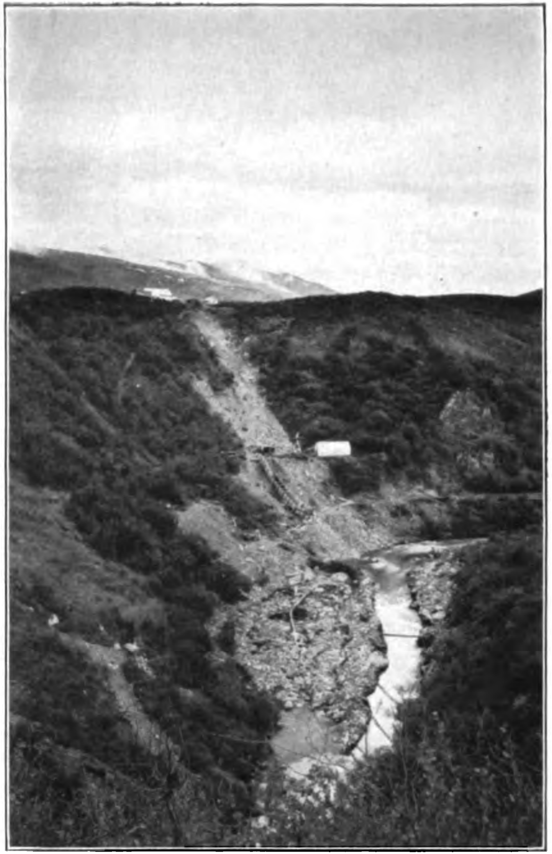
The Tammany bench is of particular interest both because of its unusual character and because it has yielded a large part of the gold produced in this district. The gold-bearing gravels are worked through a tunnel that follows the bottom of an old canyon in the slates now filled with gravel so that no trace of its presence is visible at the surface. The general course of the canyon so far as it has been traced is N. 15° E. It thus makes an angle of about 48° with the present course of Valdez Creek. (See fig. 8.)

The tunnel starts on the north side of claim No. 2 above, at an elevation approximately 60 feet above the present creek bed, and is driven across the north side of the creek claim into the adjoining Tammany bench (Pl. IX, *B*, p. 62, and fig. 9). Its length in August, 1910, was about 700 feet.

From the tunnel floor to the surface of the bench is a distance of 110 feet, which is the thickness of gravel filling in the old canyon,



A. TERTIARY CONGLOMERATE AND SANDS ON A TRIBUTARY OF PHELAN CREEK.



B. THE MONAHAN TUNNEL AND SECOND CREEK CLAIM ABOVE DISCOVERY, ON VALDEZ CREEK.

for on either side of the tunnel bedrock outcrops within a few feet of the surface of the bench. Variations in the course of the tunnel are slight and of no importance, unless the abrupt eastward turn at its end marks the beginning of a new course. Attempts to determine the position of the old canyon on the opposite side of Valdez Creek have been made, but without conclusive results.

The rocks of the canyon walls exposed in the tunnel are slate or schist. In places the walls are waterworn, and wherever exposed they rise steeply on either side. Two crosscuts were driven from different points in the tunnel, one about 100 feet to the west, the other 60 feet to the east, but the sum of these measurements exceeds the width of the canyon. The tunnel, being more nearly straight than the canyon, crosses from one wall to the other, so that the crosscuts exaggerate the width. The maximum width is probably about 100 feet.

No difference exists between the rock material in the gravel of the old canyon and that of the creek, but variations occur in the character of the deposit. The lower 50 feet of gravel in the canyon contains flat diorite bowlders with rounded edges, rounded slate and schist fragments, and fine black clay. The upper part of the filling presents a greater appearance of disorder, and contains a larger proportion of diorite bowlders, which are round rather than flat. The gravel, too, is not so clean. Probably this upper deposit is due either to a revival of glacial activity before the canyon was filled or represents the last bowlder material laid down as the ice retreated.

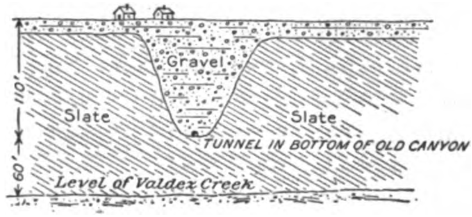


FIGURE 9.—Relation of the old canyon of the Tammany bench claim to the present channel of Valdez Creek.

Gold is found chiefly in the lower 5 feet of the gravel, although fine gold occurs in all the canyon filling. Most of it comes from the hard black clay and fine rounded slate gravel. It is coarse, flattened, and smooth for the most part, though rough pieces are present. Nuggets worth several dollars are common. As has been stated, the gold from the tunnel closely resembles that from the creek, the chief difference being a decrease in coarseness of the creek gold that becomes more pronounced downstream.

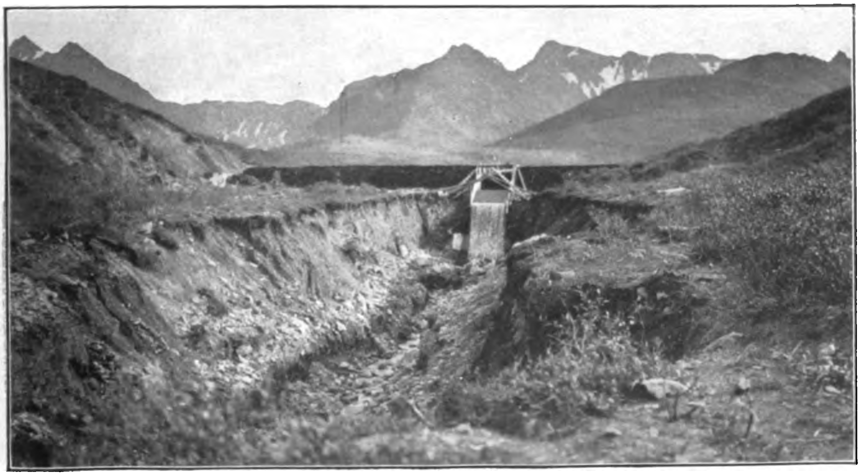
The tunnel is timbered with strong square sets and is lagged overhead but not on the sides. Great care is taken in framing the timbers and in fitting them together so that they will remain in place. Square sets are also used in the stopes but are not made of selected timber as are those in the tunnel. The stopes are generally from 25 to 35 feet wide, but reach 70 feet where the width of the gold-bearing gravel deposit was greatest.

The old canyon gravels are favorably situated for the application of hydraulic mining methods. Valdez Creek will supply water for moving the gravel without great expense, and its canyon provides an excellent dump for the disposal of tailings. A rough measurement, made a short distance above the Valdez Creek canyon at the end of August shortly after a rain, showed a flow of more than 150 cubic feet per second. This figure, however, is not intended to be used in calculations for the installation of hydraulic mining machinery. Measurements for that purpose should extend over a considerable period of time.

Steps have already been taken toward making the water available for mining purposes. A ditch, begun several years ago on the eleventh claim above Discovery, has been added to each year, till it now has a length of a little more than 4,000 feet and has reached a point 4,600 feet from the cabins on the Tammany bench. It was constructed as part of the assessment work on the claims which it crosses. The intake of the ditch is 525 feet higher than the creek at the sawmill dam on claim No. 1 below. The ditch runs over ground favorable for such construction and can be completed without unusual cost so as to furnish water for any of the claims below Timberline Creek.

The bench gravels east of claim No. 1 below are of entirely different character from those of the Tammany bench. They are in part the deposit of a small stream that joins Valdez Creek near the upper end of claim No. 2 below. This little stream drains a slight depression southeast of the creek heading near the canyon on claim No. 1 above, and at its lower end drops over the rock wall to the head of the main stream. The bedrock is slate and graywacke or fine slate grit. On the point between the little stream and Valdez Creek there are 15 to 20 feet of well-rounded gravel with a few bowlders, none of which are more than 12 to 16 inches in diameter and most of which measure not more than 10 inches. Many of the diorite pebbles are decomposed and can easily be broken with the pick, but a few are fresh and hard. In the cut from which the gravel has been mined, however, large diorite bowlders are abundant. The stream gravel carries gold which is believed to be a concentration from gravel like that on the point. Mining operations were carried on here in 1909. Water was brought from Timberline Creek, a distance of 1½ miles, by a ditch and short pipe line, and two hydraulic giants were used to move the gravel. The work was probably not very profitable, however, for it was not continued in 1910.

A. GOLD NUGGETS FROM LUCKY GULCH.



B. BOOMER AND DAM ON RUSTY CREEK.

LUCKY GULCH.

Lucky Gulch is about 6 miles east of the main camp on Valdez Creek. It is a steep gulch a little more than a mile long on the north side of Gold Hill, and was formed by a little stream whose principal source of supply is melting snow. The stream has cut a narrow V-shaped channel in slates that dip 20° N., about the same as the grade of the stream. The gulch is on the north side of the hill, and as a consequence the snow that drifts into it in winter melts slowly in summer, so that although it prevents the miners from beginning work early in the spring it provides the chief source of water later in the summer.

The gulch is too steep and narrow to permit the accumulation of a large body of gravel, but the depth of the deposits counterbalances in a measure their lack of breadth. The gravel is made up of angular fragments and slabs of slate like the bedrock, with very little well-washed and rounded material. A small amount of fine-grained diorite rock is present, as well as some quartz, but slate is the chief constituent. The slate bedrock has a well-developed cleavage and its surface in places is covered with small crystals of ottrelite.

Lucky Gulch gold is coarser than that from any other part of the Valdez Creek district. In general it is rough and many pieces contain fragments of granular quartz, although some of the gold is flattened and well worn. This difference in surface character probably indicates nothing more than a variation in the amount of rubbing and pounding the pieces have undergone in traveling down the gulch, for there is little doubt that the gold is derived from a small area and has not moved far from its source. Large nuggets form an important part of the gold product of this stream. One found in 1910 weighed 32 ounces (Pl. X, *A*), and a larger one weighing 52 ounces was taken from the gulch two or three years previously. Nuggets like these, which evidently are not far from their bedrock source, offer much encouragement to the prospector for gold lodes.

Lucky Gulch is free from the big diorite bowlders that give so much trouble on Valdez Creek. It contains a great many slabs of slate that must be moved, but most of them can be broken with a sledge or disposed of by aid of a little powder. A short season and scanty water supply counterbalance this advantage in a measure, however. The most effective method used for moving gravel in Lucky Gulch is by booming (see p. 64), but a small hydraulic nozzle and canvas hose is employed at times. Most of the gold lies on bedrock in the bottom of the gulch, and it is mined from a deep cut without disturbing the wash on either side, so that no more gravel is moved than is necessary. The walls of this cut are 25 feet high in places. Part of the gulch has been worked out, but a large amount of untouched gravel still remains.

WHITE AND RUSTY CREEKS.

White Creek joins Valdez Creek 4½ miles east of the main Valdez Creek camp. It has three branches, known as Big Rusty, Little Rusty, and Rusty creeks. These streams head in the complex of slates, tuffs, and basalt of the mountains between Valdez and Windy creeks, but their lower courses are in slates. Some prospecting has been done on White Creek, but it did not yield much encouragement, because it was carried on under great difficulty and expense, due in part to the high cost of supplies and lumber but chiefly to troubles arising from deep gravels and much water.

Prospecting on Rusty Creek has also been carried on in the face of many difficulties and great expense. During the years from 1908 to 1910, inclusive, a cut several hundred feet long and more than 25 feet deep in places (Pl. X, *B*) was made in the channel of the creek a short distance above its mouth. This cut follows the east side of what appears to be an old rock-walled channel or canyon where the northerly dipping slates of the bedrock are exposed, but is not wide enough to uncover the western wall if it is present. The gravels filling the channel include an upper deposit of unsorted glacial débris from 10 to 20 feet thick consisting of slate and basalt. Under this is a deposit of fairly well-sorted gravel and coarse sand showing a distinct cross-bedding dipping to the north. Many large bowlders on the bottom of the cut are derived from the upper bed of glacial material; most of them are basalt and come from the head of the creek, but a few of them are diorite, probably derived from the valley of Valdez Creek. Encouraging gold prospects were obtained from the projections of the rock wall on the east side of the cut and especially from the bottom of the cut where work ended in 1910. The gold is very rough and bright. Few pieces of greater value than 10 to 20 cents were found in the upper parts of the cut but the coarseness increases toward the bottom, and the deepest gold so far obtained was of such a character as to encourage the owners in the belief that they were near bedrock.

Booming has been adopted on Rusty Creek as well as on Lucky Gulch, and has made possible the large cut just described. The boomer consists of a dam with a gate (Pl. X, *B*) that opens automatically when the water level reaches a determined height and suddenly releases a large volume of water, which rushes through the cut, tearing up the gravel and carrying it away. The effectiveness of such a contrivance is hardly realized until the results of its operation have been seen.

Rusty and White creeks give more promise than any of the other tributaries of Valdez Creek for extending the known area of gold-bearing gravels, for they cut slates that have been shown to be auriferous. Undoubtedly some concentration of gold has taken place during the time the slates have been subjected to erosion, but only prospecting can determine whether the concentration has been sufficient to produce placer-gold deposits of commercial importance.

TIMBERLINE CREEK.

Timberline Creek joins Valdez Creek near the boundary between the fourth and fifth claims above Discovery. It is a little more than 2 miles long and flows through an area of slates into which a small body of diorite has been intruded. Its position with reference to Valdez Creek and its relation to Rusty and White creeks are such that it is doubtful whether it has invaded the area of mineralization from which these other streams derived much of their gold, and prospecting has yielded so little encouragement to the miners that no important amount of work has been done on the stream for several years.

DELTA RIVER DISTRICT.

The gravel bars of Delta River contain a small amount of fine gold, but not enough of the metal has been found to make them of importance commercially. Gold was panned by members of the writer's party from the gravels of Delta River near Garrett's cabin, 3 miles above the mouth of Eureka Creek, in 1910, and the presence of gold-bearing gravels in the river has been known since 1900 at least. Brooks[1] mentions a rumor of gold on Delta River as early as 1898, but was unable to verify the report. Eureka and Rainy creeks however, have produced a small amount of gold for a number of years. Mendenhall[2] states that the first prospectors on Delta River, who made their way there from Chisna River in 1900, "found colors generally on the stream bars, and what they regarded as fair prospects on Wilder Creek, or, as they called it, Rainy Creek. After the return of these men to the Chisna, a larger party was outfitted, and, returning to the region, organized the Eureka mining district. In the following spring (1901) from 200 to 250 people entered the new district and 20 or 30 of them began sluicing, but the results being unsatisfactory the field was abandoned."

The district was not entirely abandoned, however, for a few men have continued to prospect on Eureka and Rainy creeks and have taken out enough gold to give them some encouragement in the hope of final success in their effort to develop a producing district. Seven men were engaged on the two creeks in 1910—two on Eureka and the rest on Rainy Creek. They were visited by members of the topographic party at the beginning of the season, but not by members of the geologic party, and the success of the summer's work was not learned. These two streams receive nearly all their water supply from the area of rocks north of Eureka Creek correlated with the Chisna formation. It is known that intrusions of diorite rocks exist in this vicinity and it is thought from analogy to the Valdez and Slate Creek districts that the presence of these is probably connected with the mineralization.

---

[1] Brooks, A. H., A reconnaissance of the Tanana and White River basins, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 1, 1900, p. 484.

[2] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 117.

A few men were prospecting in 1910 on streams in the hills and lowland area west of Gulkana Lake about the headwater region of the western tributaries to Gulkana River, but with little success. The gravels contain a little fine gold, but so far as the writer knows the concentration is not sufficient to give them commercial value.

CONDITIONS AFFECTING MINING.

Practically all the conditions affecting mining have been referred to in previous pages, but the more important ones are brought together here for the convenience of the reader. Only the Valdez Creek district will be considered because it is the only part of the region described that has been an important producer of gold in the past or, so far as now known, gives much promise for the future.

Aside from the amount of gold contained in the gravel and the possibility of recovering it, the important conditions that affect mining have to do with transportation and the supply of water and timber for mining purposes. Many other factors, such as stream gradient and cost of labor, also have a bearing on the success of placer mining, but in most places the three first named are of most importance.

It has been mentioned (p. 20) that most of the supplies used on Valdez Creek have been brought from Valdez in winter with horses and sleds at an average cost of about 30 cents per pound. The improvements on the military road will doubtless make it possible to reduce this cost considerably and a further reduction may be brought about by sending freight part way by railroad. The cost of carrying freight from Gulkana to Valdez Creek, however, can hardly be reduced unless closer communication with a railroad shall be established, which is not likely in the near future.

Valdez Creek has a supply of water for hydraulic operations on the lower part of the creek adequate for any demands likely to be made on it. The water can be obtained by ditching over favorable ground without unusual expense and delivered with a head of 200 to 300 feet, depending on the point where it is to be used. The canyon, moreover, affords a good dumping ground for tailings, but any plan for mining must provide means for handling the great number of bowlders in the gravel. Water can not be procured under such favorable conditions above the canyon, that is, higher on the stream than the eleventh claim above Discovery, for the grade is lower and the ditches would, therefore, have to be longer. For the same reason the disposal of tailings would be more difficult.

A supply of timber for use in mining and for fuel when coal is not available is essential to the success of any mining operation. The most productive part of Valdez Creek is situated at the upper limit of spruce timber, but the hill slopes bordering the flats of Susitna River provide a supply sufficient for many years to come. Most of the larger and better trees within several miles of the sawmill on claim No. 1 below have been cut since 1903, so that it is necessary to haul logs for lumber a considerable distance. Firewood may be obtained more easily. All the logs for sawing and for fuel and all the timbers used for square sets in the tunnel are hauled to the sawmill or to the place where they are to be used before the snow melts in the spring. Cutting the timber and bringing it in is the first work that receives attention after supplies for the summer are landed on the creek.

The cost of labor is $10 a day, without board, for work during the mining season. It is, therefore, evident that this item of cost is higher than in placer-mining districts where communication with a labor market is easier. It is possible that this expense may be reduced when the line of travel over the military road becomes better established, thus making it easier for men to move about from place to place; but Valdez Creek is 65 miles from the road and is not connected with it by a trail sufficiently well marked to enable a stranger to follow it. Furthermore, there are no camps or road houses along the way where men could get food or rest.

At present there is no mail service to Valdez Creek, although mail was brought from Gulkana by private carrier during the summer of 1910. The military telegraph line which follows the road from Valdez to Fairbanks does not connect with Valdez Creek.

The miners of Valdez Creek are dependent on game for fresh meat. Most of it is obtained from the natives by trading tea, sugar, flour, tobacco, and clothing. Caribou and moose are the most important game animals, but all game is much less plentiful than when the miners first entered the region, and sheep have practically disappeared from the south side of the Alaska Range from Susitna to Delta rivers. None were seen by members of the writer's party in 1910, and the miners report that there are none. Caribou, however, are still sufficiently plentiful to provide the chief source of meat. During the summer they seek the higher parts of the Alaska Range, and their tracks are often seen along the glaciers and on the tops of high ridges where one would ordinarily expect to find sheep. Possibly they go there to seek relief from flies and mosquitoes. Toward the end of summer they come down to lower ground and often can be taken with little difficulty.

Moose, on the other hand, seek the thickets along the mountain streams in winter or early spring and return to the lowland areas in summer. They are far more difficult to find than caribou and more skill is required to shoot them after they are found. The swampy lowland between the Copper and the Susitna is an excellent country for moose.

Fish are abundant in many of the lakes and in some of the clear-water streams. Grayling are plentiful in Delta River above Eureka Creek, but, except for the salmon, the finest and largest fish in the region is a trout found in some of the lakes, such as Summit Lake and the two lakes at the head of Roosevelt Creek.

SUGGESTIONS.

A few suggestions may be of aid to the prospector. The known areas of mineralization in the headwater region of Copper and Susitna rivers are areas of slates intruded by diorite. It is believed that a genetic relation exists between the presence of gold in the slates and their intrusion by the diorites and the related porphyritic dikes and sills. It is, therefore, advisable to give attention to gravels derived from such sources, for although they can not be predicted with certainty to carry gold they are at least more favorable places for search than areas where only one of these rocks is present. Failure to find mineralized zones at the contacts of the diorite and the slate is not evidence against the influence of the igneous rocks as a factor in the deposition of gold in the slates, for the physical or chemical conditions may have been such that the influence was effective only at some distance from the intrusive mass. Gold deposits of the contact-metamorphic type are known at the head of Nabesna River but have not yet been recognized either in the Slate Creek or the Valdez Creek districts.

Those parts of the region occupied by basaltic lavas, such as the south side of Windy Creek and the area south of Eureka Creek, do not offer much encouragement for prospecting, for although some of the streams in these areas have gravels that contain fine gold it is probable that the gold has been transported there from other sources. So far as now known the same statement is true of the diorite areas.

Another characteristic which the Valdez Creek gold placers possess in common with the placers of Chititu and Dan creeks in the Nizina district and perhaps also with part of those in the Slate Creek district is that the richest of them are reconcentrations from previous concentrations in older gravel deposits. It is, therefore, important to examine the gravels of those streams in mineralized areas where the water is now cutting away and re-sorting the bench gravels—a generalization the truth of which was at once recognized by those who first discovered that the rich gravels of Valdez Creek below the Monahan tunnel owed their value to the fact that Valdez Creek, in cutting its present canyon, had tapped the previous concentration of gold in the older canyon. Although this instance is exceptional and should not be expected to be commonly duplicated, it is probably true that a very large number of rich placer deposits owe their existence to reconcentration from previous concentrations of gold in older gravel deposits and that this reconcentration may have been repeated many times.

COAL.

A small outcrop of coal occurs on Coal Creek, a tributary of Clearwater Creek, near the boundary between the slate and the basalt areas. It is on the south side of the creek about halfway from the mouth to the head and is exposed in a bed whose thickness is uncertain but is probably at least 6 or 8 feet. The coal, which is much faulted and crushed, stands on edge between walls of yellow shale that break down in angular fragments and show evidence of great disturbance. The contact between the coal and the shale on one side is a vertical fault contact, which strikes N. 65° W. Coal dust and small fragments of coal, such as coal miners call blossom, are exposed about this outcrop north of the creek for nearly half a mile, but it is doubtful whether the bed persists so far with equal thickness.

The coal is a lignite. It has been tried for blacksmith's use but proved less satisfactory than charcoal. It would be of some local value for cooking and heating if it could be conveniently carried to Valdez Creek, but it probably has no other value.

CHISTOCHINA DISTRICT.

INTRODUCTION.

The term Chistochina district is here used to include the gold-producing streams at the head of Chistochina River (Pls. III and XI), of which the most important are Slate Creek, its tributary, Miller Gulch, Chisna River, and Ruby Creek. Lime Creek or Lake Creek and the Big Four claims north of Slate Creek, on the mountain slope facing Chistochina Glacier, complete the list of localities whose gold production in 1910 contributed more than a nominal amount to the total output of the district.

The Chistochina gold placers were visited by Mendenhall in 1902, three years after the first mining locations were made.[1] The present description is based very largely on his report and contributes little to it further than to bring the account of the development up to date. The sections on "geography and drainage" and "history" are quoted from Mendenhall without change.

GEOGRAPHY AND DRAINAGE.

The gold field does not lie in the Alaska Range proper, but in a group of foothills that are separated from the main chain by a conspicuous piedmont valley, which extends 20 or 30 miles east of the head of Chistochina River and is occupied by Chistochina Glacier and the upper courses of Middle Fork, the Slana, and the Tok, and the various passes which connect these streams.

North of this feature the peaks of the great range rise abruptly to elevations of 8,000 or 9,000 feet. South of it the nearest foothills are 6,000 or 6,500 feet in height, but decrease in altitude as their distance from the axis of the range increases. These foothills are in detached groups, which, near the main range, occupy relatively large areas, the valley lowlands separating them occupying relatively small areas. This relation is in a measure reversed along the lower Chistochina near the Copper, where the foothills are often small islands rising above the general gravel plain of the Copper Valley.

The particular foothill group in which are found all of the producing claims of the district lies between Chistochina and Middle Fork and south of the western end of the piedmont valley that has been described. It is drained by tributaries of one or the other fork of the Chistochina, the largest of these tributaries being the Chisna. This small river rises in a cirque 3 or 4 miles south of the east end of Chistochina Glacier. It flows north of west for 2 miles or more, directly toward a low pass leading to Slate Creek, then turns abruptly southward and joins the Chistochina 7 or 8 miles below the mouth of West Fork. Its total length is only 12 or 13 miles. Slate Creek lies west of the upper Chisna, its lower course occupying the western end of the same depression which has controlled the upper course of the larger stream. Before entering this cross valley it flows southward for a little more than 1½ miles from the two small glacial remnants in which it rises, and after entering it follows it westward for 2 miles to the Chistochina, which it joins just at the foot of the glacier. Its total length, therefore, is not over 4 miles. Miller Gulch, the most important producer of the district, is a small northern tributary of Slate Creek, less than a mile long.

---

[1] Mendenhall, W. C., The central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, pp. 107–117.

HISTORY.

The first locations in the Chistochina gold field were made by Hazelet and Meals, in the summer of 1899. These gentlemen were among the army of argonauts who crossed the Valdez Glacier in the spring of 1898 with the idea of prospecting within the Copper River basin. Building a boat on the Klutina, they descended that stream and ascended the Copper and the Christochina, reaching the present location of Chisna post office in early July. They found encouraging prospects here, but their provisions becoming exhausted, they returned to Copper Center for a larger supply, reaching the Chisna again in August of the same year. In September they returned to Copper Center and during the following winter sledded supplies to a point on the Chistochina near the mouth of the East Fork, and from this base continued their work on the lower Chisna throughout the summer of 1899. Coarse gold was discovered at this time, and several locations were made.

In the spring of 1900 these operators, together with a number of the present Miller Gulch and Slate Creek claim owners, returned to the Chistochina with a good stock of supplies, a sawmill, and some hydraulic machinery. During this summer gold was discovered on Slate Creek and Miller Gulch by Coles, Jacobson, Kramer, and Levell, the ground staked at that time having since proved to be much the richest in the district.

TRAILS.

The regularly used winter trail from Gulkana to Chisna River and Slate Creek follows Copper River to Chistochina and ascends the stream of that name. All freight is taken in during the winter months by this route, and until recently most of the summer travel followed it also. Since the military trail was turned into a road there has been a tendency to make use of it in the summer months and thus avoid the exceedingly bad, swampy trail along Copper River. It is approximately 25 miles from Paxson on the military road to Slate Creek. The trail offers good footing for horses most of the way and presents no serious obstacles to travel, its most objectionable points being at two crossings of West Fork of Chistochina River in the canyon, where the water is confined to a single channel. Like all glacial streams, this one is subject to quick changes in the amount of water discharged from the glacier and may be impassable to-day where yesterday it afforded an easy crossing. The stream is a small one and is not hard to cross where it spreads out, but when confined to one channel it often presents difficulties. Doubtless these can be avoided when better trails are made and more favorable crossings are chosen.

MAIL AND TELEGRAPH FACILITIES.

A post office established at Dempsey, on the west side of Chistochina River near the mouth of the Chisna, has a regular bimonthly service in summer and a monthly service in winter. The mail route follows Copper and Chistochina rivers, thus serving Gakona and the telegraph station at Chistochina as well as Dempsey.

The military telegraph station at Chistochina is 35 miles from Dempsey and 45 from Slate Creek. Slate Creek, as already indicated, is about 25 miles from Paxson, the nearest telegraph station on the military road.

GOLD PLACERS.

OUTPUT.

Mining began in the Chistochina district in 1899 and continued with a steadily increasing gold production for several years until, as in all placer districts, the richest and more easily mined gravels approached exhaustion. It is estimated that the total gold production of the Chistochina district, including the year 1910, has been a little more than $1,500,000, of which Miller Gulch has produced a large proportion.

Between 40 and 50 men were employed in the Chistochina district in 1910, most of them on Slate Creek. The population is much less than it was two or three years ago, the decrease corresponding approximately to the falling off in gold production.

DETAILED DESCRIPTIONS.

MILLER GULCH.

Miller Gulch is a deep, narrow depression cut in the slates north of Slate Creek by a little stream less than a mile long. The ground was not staked till after Slate Creek was taken up, for no one suspected that its gold-bearing gravels were more valuable than those of the main stream, as later turned out to be true. There were originally eight 600-foot claims on the stream, but only seven are now held. As described by Mendenhall:

> The bedrock floor of the gulch is sheeted with coarse gravel to a depth of from 4 to 8 feet. This gravel is derived principally from the slate country rock and its diabasic and "bird's-eye porphyry" intrusives, but contains also noticeable percentages of granitic cobbles derived from the "round wash" which covers the surrounding hills. The gold is reputed to be generally distributed horizontally across the gulch, without definite pay streaks, but vertically it exhibits the usual concentration near bedrock. Ill-defined benches exist on either side of Miller Gulch at 100 or 200 feet above creek level. They are reported to prospect well, but are not now (1902) worked for lack of water. Their origin is probably connected with the glacial history of the region.

The gold of the gulch is usually flat and smooth and is very rarely found attached to quartz or country rock. It occurs as rather coarse dust and small nuggets, the largest of these reported so far weighing about 4 ounces. One-ounce nuggets are not at all rare. The gold increases in average coarseness toward the head of the gulch, whence most of the finer dust has been removed. Its assay value is said to be about $18 per ounce.

Small copper nuggets, bits of cinnabar, magnetite grains, and an occasional silver-white fragment of osmiridium are found associated with the gold in the sluice boxes.

Less mining was carried on in Miller Gulch in 1910 than in any previous year since work began there. This was not due to the exhaustion of gold-bearing gravels, but to a temporary suspension of work in order to avoid covering unworked gravels in Slate Creek with tailings. The water supply of Miller Gulch available for mining operations is small, so that it has been the custom of the two principal claim owners to use it in alternate years. In this way all the bed of the gulch has been worked out, but there still remain bench gravels that will be exploited as soon as the ground below can be used for dumping.

SLATE CREEK.

Slate Creek, as previously stated, joins Chistochina River a short distance below the glacier and is approximately 4 miles long. Its channel marks the boundary between the Chisna and the Mankomen formations, but the bedrock also includes some infolded Tertiary beds with which coal is associated. The gravel deposits of Slate Creek are to a considerable extent intimately connected with the glaciation to which the region has been subjected. Mendenhall says:

> During the recent glaciation of the region the drainage has been considerably disturbed, and in this disturbance the channel of Slate Creek has been much modified. Two shafts sunk during the last two years just east of the bed of Slate Creek, opposite Chisna Pass, reached rock at 75 and 90 feet. respectively; that is, at from 40 to 55 feet below bedrock level in Slate Creek, less than 100 yards away, a difference probably attributable to the shifting of the channel of the creek during the late occupancy of the valley by ice.
>
> It is to be noted in this connection that if Chistochina Glacier were to advance slightly the waters of Slate Creek would be dammed and forced out over the Chisna divide, thus reproducing a condition which has probably prevailed in the recent geologic past.
>
> Difficulty is also encountered in the attempt to reach bedrock on the claims immediately above the mouth of Miller Gulch. The difficulty here is probably due more to the filling from a tributary stream whose fan has spread out over the Slate Creek bottoms than to any extensive excavation because of glacial action.
>
> In that part of the upper Slate Creek channel where any sluicing has been done the gravels are from 4 to 10 feet in depth and the yield has been practically the wage of the district, $10 to $15 per day per man. As has been stated, one or two of the claims just below Miller Gulch are rich. and are being extensively worked at a profit, but the other workings on the lower part of the creek, like those on the upper, are erratic. * * *

A narrow bench 10 or 15 feet above the level of the bed of Slate Creek, opposite the mouth of Miller Gulch, was one of the first areas in the district worked. Several thousand dollars were sluiced here from a space covering a few hundred square feet. The bench presumably represents a portion of the old Miller Gulch fan, and the gold is regarded as derived from the gulch.

The Slate Creek gold is similar in form, color, and purity to that of Miller Gulch, but is not quite so coarse.

About 20 claims on the channel of Slate Creek and a number of bench claims adjoining them have been located. The first three claims above the mouth of Slate Creek are virgin ground, but are difficult to work because of the depth of gravel and the large amount of water. A hole 21 feet deep near the south side of the gravel flood plain did not reach bedrock. Tailings from above are another source of trouble on the lower claims. A dam was built near the mouth of the creek in 1910 to furnish water for booming a low bench on the north side, but was not completed in July when the district was visited.

On the fourth, eighth, and ninth claims above the mouth mining was confined to the bank on the south side of the stream. A heavy deposit of glacial material, consisting of blue clay or glacier mud and large bowlders, is exposed there. It is overlain by a deposit of frozen yellow talus or "slide" rock from 5 to 25 feet thick, derived from the mountain slope on the south. The glacial material contains gold and is exploited by undermining and caving. Bowlders are piled back from the cut to form a channel along the foot of the bank, and then the water is turned in to undermine the bank and wash away the fine gravel. Afterward the remaining gravel and gold is shoveled into the sluice boxes. This work is slow and dangerous, because the high bank of frozen gravel above sloughs off continually as it thaws and at times breaks down in large masses, so that men must be constantly on the alert and ready to jump to a place of safety.

The largest force of men at work on the creek in 1910 was near the mouth of Miller Gulch on ground that has been the richest in the district and still produces gold. This Tacoma claim, as it is called, together with the lower part of Miller Gulch, has yielded more gold than all the other claims of the district. The gravels of Slate Creek above Miller Gulch are of lower grade, and only a few men were employed there, but their contribution to the gold production of the creek is important.

BIG FOUR CLAIMS.

The Big Four claims are on a little stream that heads against Miller Gulch and flows down to Chistochina Glacier on the north side of the mountain between the glacier and Slate Creek. It has not been an important contributor to the gold output of the district, but has given employment to a few men for a number of years. It is of importance in a geologic way as giving some additional support to the belief that the slates north of Slate Creek are the source of the gold in Miller Gulch and Slate Creek rather than, as is held by some, that it came from a distant foreign source. The gold is finer than that from Miller Gulch.

RUBY CREEK.

The most important gold-producing stream in this district, after Slate Creek and Miller Gulch, is Ruby Creek, a tributary of Chisna River, which lies just east of Slate Creek and is separated from it by a broad low divide. Ruby Creek has thrown out a wide fan of gravel extending in a semicircle from the point where the creek leaves a narrow gulch in the mountains at the head of Chisna River, thus forming a long smooth slope to the west, south, and east. The creek has cut a channel ranging from 15 to 20 feet in depth in this gravel fan. The gravels are gold bearing, and mining is carried on in them and also in a short bend of filled and abandoned channel at the head of the fan just within the gulch, where for some reason the creek cut a new rock-walled channel within a few feet of its former position. So far as now known the gold content of the gravels that filled the old channel is low, though great enough to encourage prospecting and to pay its cost. The old channel is adjacent to some of the richest ground discovered on Ruby Creek. Work is hindered by snow and ice, which do not always melt in summer, so that even the water for sluicing is brought through a tunnel in the ice.

Bedrock has not been exposed in Ruby Creek where it crosses the gravel fan. The false bedrock which holds the gold is a thin gravelly clay bed only a few inches thick. In cutting its present channel Ruby Creek concentrated the gold contained in the gravel removed and left it on these clay beds or lenses. Only a few feet of gravel are shoveled into the sluice boxes and care is taken not to go below the false bedrock into the barren gravel beneath. These gravels are the source from which most of the gold from Ruby Creek is derived. Mendenhall states that the gold of Ruby Creek is "similar to that of Miller Gulch, bright yellow, smooth, and flat, only occasionally rough or in rounded pellets. A number of small nuggets have been found, the largest of which is worth $12.75. The assay value of this gold is reported to be $18 or $18.50."

CHISNA RIVER.

Chisna River occupies an intermediate position between the main stream of Chistochina River on the west and its middle fork on the east. Its valley is separated from Slate Creek by a broad low divide and from Middle Fork by another slightly higher divide. Between the stream and Chistochina Glacier is a rough, high ridge of limestone and slates belonging to the Mankomen formation, but it flows for most of its length in rocks of the Chisna formation.

Chisna River, as is seen from the description given, is separated from the area of most intense glaciation on the north, but its own valley was formerly occupied by glacial ice, and much of the unconsolidated deposits are the products of glaciation. It is evident, however, that these deposits are not entirely derived from within the valley, but were in part poured into it from east and west when the valleys of the two branches of Chistochina River were filled with ice and part of their water and débris was discharged over the two low divides previously mentioned into the valley of Chisna River.

When Mendenhall visited the district in 1902 he found that mining developments were confined to the upper and lower parts of the river. He gives the following description of the stream:

> In both of these regions bedrock had been reached on some of the claims at varying and usually not excessive depths, and wherever found it carried sufficient gold to enable the operators to wash the gravel at a profit.
>
> Throughout the intermediate portion of the river the bedrock lies at unknown depths beneath a mantle of glacial material. In one place, one-half mile above the mouth of Powell Gulch, a shaft was sunk from creek level through 21 feet of compact till into an underlying bed of sand, which admitted water and forced a suspension of operations. It is improbable that the sorting and concentrating effect of water throughout this middle portion of the Chisna Valley has at any postglacial time been operative down to bedrock, so that, even could the latter be reached, it is unlikely that gold in sufficient quantities for profitable exploitation would be found. The clay layers within the glacial deposits which are reached in prospecting carry colors, but are not sufficiently rich to invite extensive operations.
>
> * * * * * * *
>
> The operations along this [the lower] portion of the Chisna Valley are confined to a group of properties within 2 or 3 miles of the mouth of the river. They extend through the canyon and for short distances above and below it, where alone bedrock is accessible. * * *
>
> Bedrock is easily accessible through the canyon, but the latter is so narrow that the bars not swept by the swift current are very small and probably carry but little gold. At the mouth of the canyon bedrock is easily reached, but having a somewhat greater slope downstream than the river it soon passes below a point where it is at present practicable to reach it in sluicing. It is reported that bedrock lies only from 4 to 8 feet below the surface of the flood plain for a considerable distance above the canyon, but since there are many coarse bowlders in the flood-plain material it can not be handled to advantage by ordinary sluicing methods. It is believed that hydraulic work at this point will prove profitable.
>
> The gravels contain a considerable variety of rock types, contrasting strongly in this respect with those of Slate Creek, Miller Gulch, and the upper Chisna. Such a contrast is of course to be expected, because the gravels of the latter streams are derived from limited areas within the small drainage basins of the creeks themselves, where few rock varieties are known, while the gravels of the lower Chisna are of all the various types in the much larger Chisna

basin, and probably also of material brought from outside sources by glacial action.

The gold from the lower Chisna is much like that from Slate Creek and Miller Gulch in general appearance, but is finer and somewhat more uniform in grain. Nuggets are rare, but flakes one-eighth inch or more in diameter are abundant. An assay value of $18.72 per ounce is reported.

The developments have not yet determined fully the values to be won, but the gravels below the canyon are said to run from 1.7 to 5.5 cents per pan, with a maximum of $1 on bedrock. A small corner of Discovery claim, just at the head of the canyon, is reported to have yielded $1,000 as the result of a few weeks' work with a short string of sluices, so that the available gravels here, if carefully handled by hydraulic methods, should yield good profits.

In 1910 the work done on Chisna River was in the nature of assessment work and was confined to the lower part of the stream. Considerable ground is held there by different persons, who are awaiting the time when the introduction of hydraulic machinery or other economical methods shall make mining more profitable. At present the price of labor and supplies prevents development of much of the gold-bearing gravels, for with wages at $10 per day and the cost of freighting at 20 to 25 cents per pound none but the richest gravels can be exploited at a profit.

At Dempsey, on the west side of the Chistochina, near the mouth of Chisna River, are deposits of bench gravels that carry fine gold. Prospecting has been conducted there for a number of years in the expectation of discovering a definite pay streak, but without much success as yet. The principal work done is represented by a tunnel driven into the gravel bench.

That the gold of Chisna River is chiefly derived from the Mankomen formation is indicated by the fact that, so far as the writer knows, those streams cutting rocks of the Chisna formation are not gold-bearing except where they have received some contribution of foreign gravel from the north. Rich pay streaks with coarse gold should therefore not be expected on the lower Chisna and Chistochina except where glaciation has brought about unusual conditions of transportation, for the common experience in gold-placer districts is that the gold becomes finer and more widely distributed in the gravel as it travels farther from its source. When the high-bench gravels are known to carry gold, particular attention should be given to streams that are cutting channels through them or undermining their banks, for in such places a reconcentration is going on that may give a deposit of economic importance where it would not otherwise exist. Where there is no reconcentration of this kind the best hope of the prospector is in the discovery of large supplies of low-grade gravels that may be exploited in an extensive way by economical methods.

LIME CREEK.

Lime Creek is a tributary of the middle fork of Chistochina River heading against Chisna River; it appears on the older maps under the name of Lake Creek. Morainal topography characterizes much of the valley of Lime Creek from its head to the main river valley and affords abundant evidence that this region was at one time thickly covered by ice.

Placer-mining operations are conducted on a bench on the north side of Lime Creek, well above the stream and about 1½ or 2 miles east of the divide between Lime Creek and Chisna River. The gravels here are evidently largely of glacial origin. The section exposed in mining shows about 6 feet of heavy bowlder wash resting on blue glacier clay or mud containing small angular rock fragments, which is in turn overlain by more of the heavy bowlder wash, the whole section having a thickness of 30 to 40 feet. A large amount of greenstone, associated with slate, limestone, conglomerate, and granite, is present in the deposit. The richest gold deposit is contained in a rusty gravel seam on the blue-clay bedrock. Copper nuggets ranging in size from shot to pieces of several pounds are caught in the sluice boxes. They resemble those of Chititu and Dan creeks in the Nizina district and like them are probably derived from copper deposits in basalts or greenstones, such as are exposed in the mountain northwest of Lime Creek.

ORIGIN OF THE GOLD.

From his study of the placer deposits of the Chistochina district, Mendenhall reached the conclusion that the gold was derived from an area of local metamorphism in the slates of the Mankomen formation, and gave the following account of its origin and the conditions governing its disposition:

> The coarsest gold of the Chistochina field is found in Miller Gulch, in Slate Creek, and at the head of the Chisna. That taken from the lower Chisna is finer in grain and has a higher assay value, although in other respects it resembles the product of the headwaters. It is therefore considered probable that all of the gold of the field has been distributed from the region about the sources of the producing streams, but there is a lack of unanimity as to the manner of its occurrence there.
>
> Many operators plausibly maintain that it is derived from the "round wash," which is particularly heavy about the head of Miller Gulch and Slate Creek. This deposit of cobbles is also present on the divide between Ruby Gulch and the stream next east, so that the advocates of this theory are able to prove that each stream at present worked to a profit drains an area in which the "round wash" is found. They likewise regard the smooth surface of the gold as evidence that it is water worn and has therefore been brought, like the "round wash," from some extraneous source.
>
> Some facts, however, are distinctly opposed to this hypothesis. Others seem to admit of as ready explanation on another basis.

A small stream on which a group of claims known as the "Big Four" has been staked heads opposite Miller Gulch and flows down to Chistochina Glacier. The heaviest deposit of the "round wash" known in the region occurs on the slopes drained by this brook, which seems, therefore, to be more favorably situated than Miller Gulch relative to this deposit as a source of gold; but the Big Four claims yield fine gold in moderate amount and are not to be compared in richness to Miller Gulch. Furthermore, Ruby Gulch and the creek next east of it seem to be equally favorably situated in relation to the deposit of the "wash," which occupies the divide between them, yet one has yielded operators a handsome return and the other is not profitable.

It is even more significant that the sources of the gold-bearing creeks are all within an area whose extent coincides with a region of local metamorphism in the Permian shales, and that no other metamorphosed areas of these beds and no other gold districts within them are known. Where they have been metamorphosed an incipient cleavage is developed and the shales carry a few narrow quartz stringers. It is believed that the flat, smooth character of much of the gold is sufficiently accounted for by its origin in these shales and by its purity and consequent softness, which lead to a rapid smoothing and polishing with but little transportation.

It is therefore concluded that the gold is derived from these Permian rocks and that in its genesis it is related to the local metamorphism which they have suffered. It is evidently post-Permian in age, and since Eocene beds deposited unconformably upon the Permian are but little folded and wholly unmetamorphosed, it is probably also pre-Eocene.

INFLUENCE OF GLACIATION.

Ice has been an important and often disturbing agent in the distribution of the gold within the district. To this agent must be attributed the irregularities in depth of bedrock, the potholes which occasionally exist in the stream bed, and the changes in drainage which are to be inferred in many instances. The coarseness of the gold now found in the lower Chisna, if, as believed, it has been derived from the district at the heads of the Chisna and of Slate Creek, is probably due in part to the action of the ice as a carrier. Furthermore, the canyon on the lower Chisna, with the short stretches above and below it within which bedrock is accessible, is no doubt due to the superposition of the stream, in the process of readjustment during the withdrawal of the ice from the lower Chisna Valley, upon the granite ridge through which the canyon is cut. To this agent again must be attributed the heterogeneous filling of the middle Chisna Valley and the burial of bedrock there beyond the reach of the miner.

ECONOMIC CONDITIONS.

The high cost of labor and supplies, due to the remoteness of the district from the coast and to the difficulties of freighting, has already been spoken of and need not be repeated, but it should be said that there has been improvement in these respects since the early days of mining here. The other important conditions affecting mining are thus summarized by Mendenhall:

> Another condition which tends to raise the cost of production in the region is the absence of wood on the upper Chisna and on Slate Creek and Miller Gulch. These streams lie well above timber line, and wood, for whatever purpose desired, must be hauled from the nearest timber, 5 or 10 miles distant.

This work is accomplished in the early spring over the snow, before it is possible to begin mining operations, but with the high wages that prevail this increases considerably the cost of living. On the lower Chisna there is sufficient timber for all present needs.

The length of the working season is rather short on the upper creeks, where the water freezes in the sluice boxes usually by September 15 or 20, and it is sometimes as late as July before the snow is melted from the upper portions of gulches, so that a working period of not more than three months is to be counted upon for this part of the district. Here again the lower Chisna is more favorably situated, since the fall freezing is delayed for two or three weeks and the snow melts away earlier in the spring.

INDEX.

A.

Page.

- Acknowledgments to those aiding 9, 11
- Alaska, southern part of, outline map of 11
- Alaska Range, structure of, features of 45–47
  - structure of, figures showing 46
  - topography of, plate showing 52

B.

- Basalt Mountains, on Windy Creek, plate showing 40
- Basic lavas and tuffs, character, age, and distribution of 29–30
- Bench gravels, of Valdez Creek, character of. 60–62
- Big Four claims, gold placers of 74–75
- Big Rusty Creek, rock glacier on, plate showing 44
  - upper valley of, plate showing 40
- Birch Creek schist, character and distribution of 24–26
- Brooks, A. H., preface by 7–8

C.

- Carboniferous rocks, character and distribution of 27–30
- Chisna River, gold placers of 75–77
- Chistochina district. drainage, topography, and history of 70–71
  - economic conditions in 79–80
  - glaciation in 79
  - gold placers of 72–79
  - transportation and communication in 71–72
- Chistochina River, structure of Alaska Range near, figure showing 46
- Climate, general features of 15–16
- Coal, occurrence and value of 69
- Conglomerate with Triassic sediments, plate showing 32
- Copper River, section of Pleistocene on 43
- Copper River region, central part of, geologic map of .... In pocket.
- Copper River valley, former and present land surfaces of, figure showing 50
- Creek gravels of Valdez Creek, character of 58–60

D.

- Delta River, structure of Alaska Range near, figure showing 46
- Delta River district, gold placers of 65–66
- Diorite intrusive, in Jurassic rocks, age of 35
- Drainage, of Chistochina district, general features of 70–71
  - of Gulkana-Susitna region, general features of 13–14

E.

Page.

- Economic geology, account of 53–69
- Eocene land surface, figure showing 50
- Eureka Creek, landslide on tributary of 32
- Explorations, in Gulkana-Susitna region, account of 9–10

F.

- Fish, abundance of 68
- Fossils, Triassic, identifications of 33
- Freighting, cost of 20

G.

- Game, abundance of 67–68
- Geography, of Chistochina district, general features of 70–71
  - of Gulkana-Susitna region, general features of 11–21
- Geologic work, in Gulkana-Susitna region, account of 9–10
- Geology. *See* Stratigraphy; Structure; Historical geology; Economic geology; *also particular periods and formations.*
- Giffin, C. E., work of 9
- Glacial deposits, character and distribution of. 39–41
- Glaciation, in Chistochina district, effect of ... 79
  - in Gulkana-Susitna region, effect of 51–53
- Gold, conditions affecting mining of 66–68
  - in Valdez Creek district, distribution and values of 53–65
    - history and production of 53–54
    - lode deposits of, character and distribution of 56–57
    - placer deposits of, character and distribution of 57–65
    - source of 55–56
  - suggestions regarding mining of 68–69
- Gold placers, of Chistochina district, character and distribution of 72–79
  - origin of gold of 79
  - output of 72
- Grass, character and distribution of 17–18
- Gulkana Glacier, plate showing 52
- Gulkana-Susitna region, geologic map of. In pocket.
  - location of 11–12
    - figure showing 11
  - topographic map of .... In pocket.

H.

- Historical geology, account of 47–53
- History, of Chistochina district, account of ... 71

J. Page.

Johnson, B. L., work of.... 9
Jurassic rocks, character and distribution of.... 33–35

K.

Klawasi River, section of Pleistocene on.... 42
Klutina River, section of Pleistocene on.... 43

L.

Labor, cost of.... 67
Lake gravels, character and distribution of.... 41–45
Landslide, plate showing.... 32
Land surfaces, condition of, in Eocene epoch and at present, figure showing.... 50
Lavas, character and distribution of.... 29–30
Lime Creek, gold placers of.... 78–79
Lode deposits, of gold, on Valdez Creek, character and distribution of.... 56–57
Lucky Gulch, gold nuggets from, plate showing.... 62
  gold placers of.... 63

M.

Mail facilities, of Chistochina district, character of.... 72
  of Valdez Creek district, character of.... 67
Mendenhall, W. C., on Chistochina district.... 70–71, 72–74, 76–80
  on stream and lake gravels.... 42–43
Miller Gulch, gold placers of.... 72–73
Mining, conditions affecting.... 66–68
  suggestions regarding.... 68–69
Mining development, on Valdez Creek, data on.... 58
Monahan tunnel, plate showing.... 60
Moraines, character and distribution of.... 39–41

P.

Phelan Creek, Tertiary conglomerate on tributary of, plate showing.... 60
Placer deposits, character and distribution of.... 57–65
Pleistocene deposits, sections of, figures showing.... 42, 43
Population, estimate of.... 18–19
Pre-Carboniferous (?) rocks, distribution, character, and age of.... 26–27
Pre-Ordovician (?) rocks, character, age, and distribution of.... 24–26

Q.

Quaternary deposits, deposition, character, and distribution of.... 39–45

R.

Relief, character of.... 12–13
Rock glacier, occurrence and nature of.... 41
Ruby Creek, gold placers of.... 75
Rusty Creek, boomer and dam on, plate showing.... 62
  gold placers of.... 64–65

S.

Slate Creek, gold placers of.... 72–73
Stanton, T. W., fossil determinations by.... 33

Pa
Stratigraphy, detailed account of.... 21–
  general outline of, in Chistochina district.... 23–
    in Gulkana-Susitna region.... 21–
  geologic column representing....
Stream gravels, character and distribution of.... 41–
  figures showing sections of.... 42,
Structure, general features of.... 45–
  of Alaska Range, figures showing....
Supplies, sources of....
Surveys, in Gulkana-Susitna region, account of.... 9–
Susitna River, headwaters of, topographic map of.... In pocke
  region near headwaters of, geologic map of.... In pocke

T.

Tammany bench claim, relation of to Valdez Creek, figure showing....
Tertiary conglomerate, plate showing....
Tertiary rocks, character, distribution, age, and correlation of.... 35–
Timber, availability of, for mining....
  character and distribution of.... 16–
Timberline Creek, gold placers of....
Topographic development, account of.... 49–
Topography, general features of.... 12–
Trails, in Chistochina district, character of....
  in Gulkana-Susitna region, character and number of.... 19–
Transportation, facilities for.... 19–
Triassic rocks, character, distribution, age, and correlation of.... 31–
Triassic sediments, conglomerate associated with, plate showing....
Tuffs, character and distribution of.... 29–

V.

Valdez Creek, bowlder deposits on, plate showing....
  claims along, figure showing....
  geology of and mining development on.... 57–
  lower part of, plate showing....
  relation of, to Tammany bench claim, figure showing....
  "soil flows" near head of, plate showing....
  tunnel and claim on, plate showing....
  wing dam in canyon of, plate showing....
Valdez Creek district, conditions affecting mining in.... 66–
  gold placers of.... 57–
Vegetation, character and distribution of.... 16–

W.

Water, availability of, for mining.... 66–
White Creek, gold placers of.... 64–
  upper valley of, plate showing.... 4
Windy Creek, basalt mountains on, plate showing.... 4
Wing dam in canyon of Valdez Creek, plate showing.... 5
Witherspoon, D. C., work of....

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 499

COAL NEAR THE BLACK HILLS

WYOMING–SOUTH DAKOTA

BY

R. W. STONE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

CONTENTS.

Page.
Introduction........ 5
Geology........ 7
  Structure........ 7
  Stratigraphy........ 8
    Spearfish and Sundance formations........ 9
    Morrison shale........ 9
    Lakota sandstone........ 9
      Occurrence and character........ 9
      Cambria........ 10
      Plum Creek........ 12
      Oil Creek........ 13
      Aladdin........ 15
    Fuson shale........ 15
    Dakota sandstone........ 16
    Graneros shale........ 17
Coal........ 17
  Introduction........ 17
  Occurrence........ 18
    Aladdin........ 18
    Sundance........ 21
    Mason Creek........ 24
      Ridge west of Inyankara Mountain........ 24
      Miller coal mine........ 24
      Philpott Canyon........ 25
      Dry Creek........ 27
    Skull Creek........ 27
    Plum Creek........ 31
    Cambria........ 32
      History........ 32
      Mines and method of mining........ 33
      Character of the bed........ 34
      Village and mine equipment, by C. T. Lupton........ 38
        Population and buildings........ 38
        Railroad facilities........ 39
        Water supply........ 39
        Mechanical equipment........ 40
          Workshops........ 40
          Mining machinery........ 40
          Ventilation........ 42
          Tipple........ 42
        Output........ 42
      Mount Zion........ 43
      Little Oil Creek........ 43

Coal—Continued.
Cambria—Continued. Page.
Robbersroost Canyon........ 44
Salt Creek........ 44
Edgemont........ 45
East side of Black Hills........ 48
Character of the coal........ 48
Physical properties........ 48
Coking qualities........ 50
Chemical properties........ 51
Selection of samples........ 51
Composition........ 52
Tests........ 57
At the United States Geological Survey fuel-testing plant........ 57
Miscellaneous tests........ 60
Summary of tests........ 62
Gold in Cambria coal........ 63
Prospects for the future........ 64

ILLUSTRATIONS.

Page.
PLATE I. *A*, Lakota and Dakota sandstones on Little Oil Creek, near Cambria, Wyo.; *B*, Dakota sandstone dipping below surface 1 mile north of Newcastle, Wyo........ 10
II. Typical cliffs and talus of massive Dakota sandstone........ 16
III. *A*, Stilwell Coal Co.'s mine and Lakota sandstone at Aladdin, Wyo.; *B*, Lakota sandstone in Camp Canyon, near Cambria, Wyo........ 18
IV. Sections of coal beds near Black Hills........ 34
V. *A*, Cambria Fuel Co.'s tipple at Cambria, Wyo.; *B*, View of Cambria, Wyo........ 38
VI. Opening on coal at Mount Zion ranch, near Cambria, Wyo........ 42
VII. Photographs showing physical characters of different coals........ 48
FIGURE 1. General map of Black Hills region, showing areas covered by large-scale maps........ 6
2. Sketch map of mines and prospects near Aladdin, Wyo........ 19
3. Coal area in secs. 13 and 24, T. 51 N., R. 64 W........ 22
4. Map showing location of Sundance and Mason Creek prospects........ 23
5. Sketch map showing location of prospects at Holwell ranch, northwest of Newcastle, Wyo........ 28
6. Extent of mine workings at Cambria, Wyo........ 33
7. Map showing location of coal near Edgemont, S. Dak........ 46
8. Diagrammatic section of coal bed exposed in bank of Cheyenne River, east of Edgemont, S. Dak........ 47

COAL NEAR THE BLACK HILLS, WYOMING-SOUTH DAKOTA.

By R. W. Stone.

INTRODUCTION.

Nine townships on the west side of the Black Hills were examined by the writer in the fall of 1908 for the purpose of making a classification of the public lands with respect to coal. (See fig. 1.) The townships examined were T. 45 N., Rs. 61–62 W.; T. 46 N., Rs. 61–62 W.; T. 47 N., Rs. 62–63 W.; T. 48 N., Rs. 62–63 W.; and T. 49 N., R. 63 W. This area is in the Sundance and Newcastle quadrangles, and its geology is mapped and described in folios Nos. 107 and 127 of the Geologic Atlas of the United States. The field examination was therefore confined to the outcrop of the coal horizon and the areas underlain by coal as shown in the folios. All known coal exposures and prospects along the coal horizon were examined and a small amount of excavating was done. C. T. Lupton, M. I. Goldman, and F. D. Morrison assisted in the field work, which occupied about three weeks. In June and July, 1909, the writer spent a week studying the coal near Aladdin and Sundance, Wyo., and Edgemont, S. Dak., for land classification purposes.

When the field examinations were made publication of their results was not contemplated, but after the data had been used for land classification the writer found time in 1911 to arrange them in a form suitable for publication, which seemed desirable because the two field examinations included all known important coal exposures near the Black Hills. This report is made for the purpose of assembling the information concerning coal in the reports cited below, together with the considerable amount of new data obtained by the writer.

The following list includes papers which deal with the coal resources of the Black Hills. All of them, except the four last cited, are publications of the United States Geological Survey.

Darton, N. H., Newcastle folio (No. 107), Geol. Atlas U. S., 1904.

Darton, N. H., and **Smith**, W. S. T., Edgemont folio (No. 108), Geol. Atlas U. S., 1904.

Darton, N. H., Sundance folio (No. 127), Geol. Atlas U. S., 1905.

Darton, N. H., and O'Harra, C. C., Aladdin folio (No. 128), Geol. Atlas U. S., 1905.

Darton, N. H., The coal of the Black Hills, Wyoming: Bull. No. 260, 1905, pp. 429–433.

Darton, N. H., Geology and underground-water resources of the central Great Plains: Prof. Paper No. 32, 1905, pp. 374–379.

Darton, N. H., Geology and water resources of the northern Black Hills and adjoining regions in South Dakota and Wyoming: Prof. Paper No. 65, 1909, pp. 93–94.

Darton, N. H., Geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: Twenty-first Ann. Rept., pt. 4, 1901, pp. 582–584.

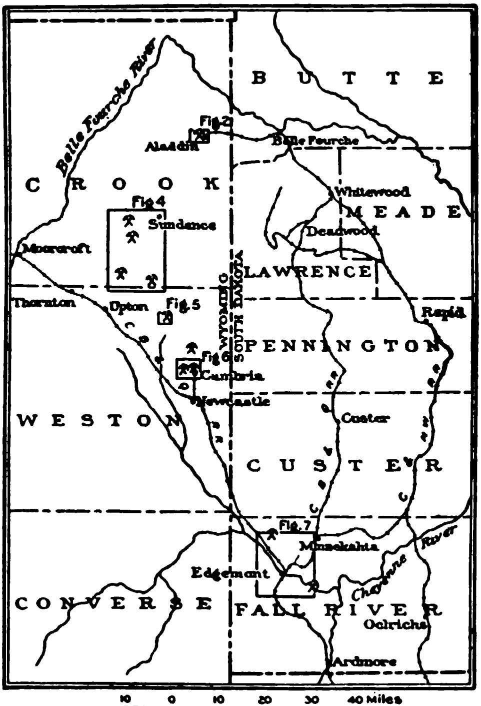


Figure 1.—General map of Black Hills, showing areas covered by large-scale maps.

Jenney, W. P., Field observations in the Hay Creek coal field: Nineteenth Ann Rept., pt. 2, 1899, pp. 568–593.

Parker, E. W., Holmes, J. A., Campbell, M. R., committee in charge, Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Bull. No. 261, 1905, pp. 28–29, 59, 83, 115–117, 119.

Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper No. 48, 1906.

Holmes, J. A., in charge, Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: Bull. No. 290, 1906, pp. 224–229.

Mineral Resources of the United States for 1900, 1901, p. 535.

Mineral Resources of the United States for 1908, 1909, p. 196, and for previous years.

Storrs, L. S., The Rocky Mountain coal fields: Twenty-second Ann. Rept., pt. 3, 1902, p. 440.

Chance, H. M., The resources of the Black Hills and Bighorn country, Wyoming: Trans. Am. Inst. Min. Eng., vol. 19, 1890–91, 1891, pp. 49–58.

Chance, H. M., The Discovery of New Gold Districts: Trans. Am. Inst. Min. Eng., vol. 29, 1899–1900, 1900, pp. 227–228.

Chenhall, J. W., Coal mining by mechanical appliances: Min. Proc. Inst. Civil Eng., London, vol. 139, 1900, pp. 323–333.

Todd, J. E., Mineral building materials, fuels, and waters of South Dakota: Bull. S. Dak. Geol. Survey No. 3, 1902, p. 110–111.

Several lengthy excerpts, mostly geologic sections, have been taken from N. H. Darton's reports for the chapter on stratigraphy. The writer desires to acknowledge indebtedness to him also for many helpful suggestions and cordial interest in this paper. The notes for the chapter on the civic and mechanical equipment at Cambria were collected by C. T. Lupton, and those pages were written by him. The writer wishes to thank L. T. Wolle, secretary and treasurer, and W. E. Mouck, superintendent, of the Cambria Fuel Co. for much valuable information and kindly assistance. He is indebted to C. T. Lupton, M. I. Goldman, and F. D. Morrison, who assisted him in the field, for their efficient work in searching for and examining coal prospects under weather conditions at times most disagreeable. The work was done under the supervision of M. R. Campbell, geologist in charge of the economic geology of fuels, to whom the writer is indebted for helpful suggestions and criticisms.

GEOLOGY.

STRUCTURE.

The Black Hills, located on the boundary between South Dakota and Wyoming, form an important geologic and physiographic interruption in the Great Plains, which extend from the foot of the Rocky Mountains eastward to the Valley of the Mississippi. Rising several thousand feet above the plains, and well covered with timber and other vegetation because of the abundant rainfall, they contrast strongly with the surrounding treeless plains. Structurally, they constitute a dome-shaped uplift, in which sedimentary rocks much older than those forming the surface of the Great Plains were lifted high above their general level. Erosion has unroofed this dome, exposing successive formations in concentric rings around the central hills.

The salient features of the uplift are (1) a central area of crystalline rocks forming high ridges which culminate in Harney Peak; (2) a limestone plateau with infacing escarpment; (3) a continuous trough, the Red Valley, completely encircling the plateau; and (4) an outer rim of flat-topped ridges which in most parts presents a steep face toward the Red Valley and a fairly flat surface sloping gradually away from the central area.

In early Tertiary time, probably during the period of uplift in which the doming occurred, there was more or less igneous activity, which resulted in the development of laccoliths, largely composed of monzonite and syenite porphyry.

The central area is eroded in Archean and Algonkian granite, schist, and quartzite, which contain valuable minerals in many places. High mountains in this area are separated by parklike valleys which narrow to canyons where the streams pass through the surrounding limestone plateau.

The general level of the limestone plateau is higher than that of the igneous area, so that the central hilly group forms a basin. For many miles the limestone presents a line of cliffs rising several hundred feet above the valleys of the central area and locally it attains altitudes almost equaling Harney Peak. All around the Black Hills the limestone plateau slopes outward and is notched by deep canyons of the streams escaping from the open valleys of the inner basin.

The encircling Red Valley is bordered on the inside by the long slopes of the limestone plateau and on the outside by the escarpment of the outer rim. Although the valley appears to be continuous the main streams from the center of the hills cross it without much digression, but the divides between them are so low that the valley character of the encircling depression is conspicuous. The red color of the rocks and soil and the lack of trees are distinctive. The Red Valley commonly is 2 to 3 miles wide, but becomes narrower where the rocks dip at a greater angle or where interrupted by minor doming, as at Inyankara and Strawberry mountains, on the west side of the Black Hills.

The outer rim of the hills at the north and south, and locally along the middle western section, spreads out in a long, gentle apron, sloping away from the uplift. A fine example of the smooth plateau surface sloping away from the dome and presenting an infacing escarpment is seen north of Edgemont, S. Dak., and also southwest of Sundance, Wyo. This ridge, or slightly tilted plateau, is made by the massive Dakota and Lakota sandstones, and, since coal is found only in these formations, is the only part of the Black Hills uplift with which this report is concerned. All the coal known in the Black Hills is in the outer rim, and with the exception of some minor localities near Edgemont, S. Dak., is in Wyoming.

Knowledge of only a portion of the geologic column is essential to an understanding of the relations of the coal, and therefore only the stratigraphy from the top of the Sundance to the Graneros shale is described in detail.

The following description of the geologic formations is adapted from that by N. H. Darton in the Newcastle, Edgemont, Sundance, and Aladdin folios.[1]

STRATIGRAPHY.

The formations mentioned in the following pages, named from youngest to oldest, are Cretaceous: Graneros shale, Dakota sandstone, Fuson shale, Lakota sandstone; Jurassic (?): Morrison shale; Jurassic: Sundance formation; Triassic (?): Spearfish formation.

---

[1] Newcastle folio (No. 107), Edgemont folio (No. 108), Sundance folio (No. 127), Aladdin folio (No. 128); Geol. Atlas U. S., U. S. Geol. Survey, 1904, 1905.

SPEARFISH AND SUNDANCE FORMATIONS.

The Spearfish formation, commonly known as the "Red Beds" by reason of its color, is the most easily recognized stratigraphic unit in the area. Its material is red sandy shale with intercalated beds of gypsum, and it varies in thickness from 450 to nearly 700 feet.

Lying upon the Spearfish formation is the Sundance formation, of Jurassic age, composed of sandstone and shale so different lithologically from the red beds below and the Morrison shale above as to be readily recognizod. Buff sandstone and greenish gray shale with fossiliferous limestone are characteristic. The thickness is from 200 to 350 feet.

MORRISON SHALE.

Unconformably upon the Sundance formation lies a shale formation known as the Morrison, which is of Jurassic or Lower Cretaceous age. It averages about 150 feet in thickness and consists of massive shale with thin layers of fine green sandstone. Buff, pale-green, and maroon colors give character to the general drab color of this shale and make the formation readily recognizable. The soft color of the weathered outcrop can not easily be mistaken for the buff of the Sundance or the bright red of the Spearfish formation.

The Morrison shale outcrops in a narrow belt under the cliffs of Lakota sandstone along the east face of the so-called Hogback Ridge in Wyoming. The outcrop is often obscured by talus from the sandstone cliffs above and by soil derived from its own disintegration. Good exposures are to be seen along Mason Creek near the county line, on Skull Creek near the Holwell ranch, in Black Canyon and along Oil Creek, and in the long straight bluff of the table on the west side of Salt Creek. East of Salt Creek it is extensively exposed by the removal of the Lakota sandstone. The formation is poorly exposed near Aladdin but appears to be about 60 feet thick.

Its relations and fauna in other regions suggest that the Morrison is of fresh-water origin. It contains fossil bones of saurians which some paleontologists deem to be of late Jurassic age; others class them as early Cretaceous.

LAKOTA SANDSTONE.

Occurrence and character.—The prominent escarpment which flanks the encircling outer rim of the Black Hills is produced by the massive hard sandstones of the Lakota and Dakota formations. The ready weathering of the soft shale beneath enhances the relief and the sandstones outcrop in high cliffs. Owing to low dip and deep canyons, the outcrop of the main body of sandstone is very long and is flanked by numerous outlying buttes.

The Lakota sandstone is usually from 150 to 300 feet thick, and is composed of coarse-grained, massive, and cross-bedded sandstone with thin partings of shale. The color is commonly buff but may be light gray or even white. Some of the basal sandstone is markedly white and of sugary texture; much white sandstone is found in Oil Creek valley, especially west of the T E ranch.

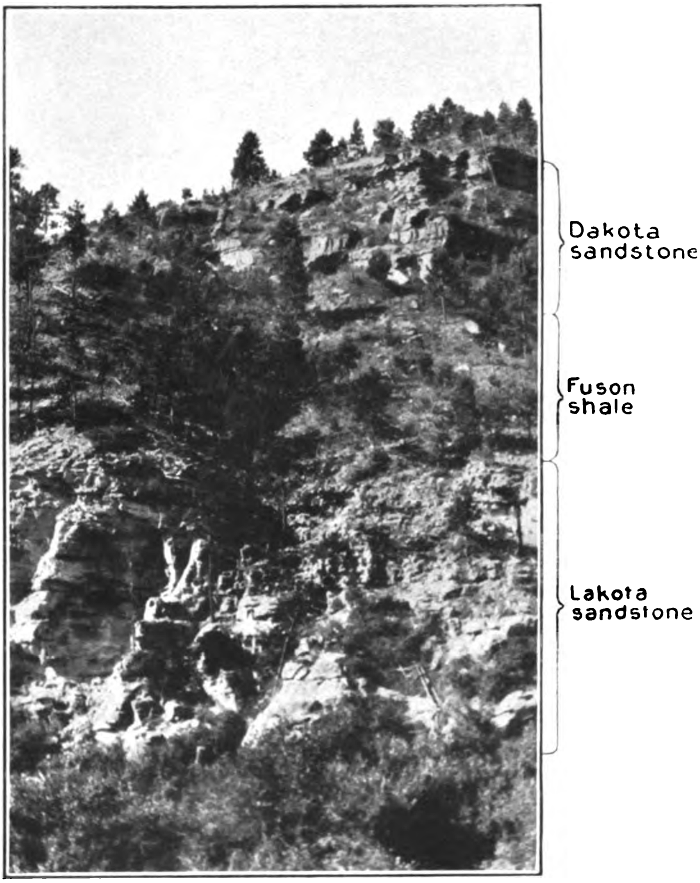
At or near the base there is a coal horizon in which occurs an erratic bed of bituminous coal. In a small area about Cambria the coal is from 4 to 10 feet thick, and at the Holwell ranch on Skull Creek it is known to be from 6 to 9 feet thick. Elsewhere, however, the bed is either badly broken by partings, is very thin, or is represented by carbonaceous shale.

Cambria.—Typical sections of the Lakota and closely associated formations in the vicinity of Cambria, measured by Darton and published in the Newcastle folio, are here given, the first being compiled from surface exposures near Cambria and from the record of a bore hole sunk on the plateau and passing down through the Antelope mine.

Section of Lakota and associated formations at Cambria, Wyo.

	Feet.
Dakota:	
Sandstone, thin bedded, at top of table	20
Sandstone, hard, massive, buff colored	40
Fuson:	
Shale and talus [concealed beds]	20
Lakota:	
Sandstone, light colored, conglomeratic in part	60
Talus [concealed beds] and sandstone ledges	70
Sandstone, light-gray, soft, fine-grained	50
Coal	7
Sandstone, hard, light brown	5
Sandstone, soft, dark brown	2
Sandstone, light-gray, moderately hard	1½
Coal with sandstone, shale, and pebbly layers	½
Sandstone, dark-gray, soft	1
Coal, shales, and sandstone	2
Morrison:	
Clay, gray	3
Sandstone, light-gray, moderately hard	1½
Clay	7½
Sandstone, gray, upper half very hard	4
Shale with some thin sandstones	54+

In the canyon of Little Oil Creek below Cambria high walls of Lakota sandstone surmounting a slope of Morrison shale, from 40 to 90 feet high, are capped by Dakota sandstone with underlying Fuson shale (Pl. I, *A*). A section 2 miles above Newcastle is as follows:



A. LAKOTA AND DAKOTA SANDSTONES ON LITTLE OIL CREEK NEAR CAMBRIA, WYO.

B. DAKOTA SANDSTONE DIPPING BELOW SURFACE, 1 MILE NORTH OF NEWCASTLE, WYO.

Section of canyon of Little Oil Creek above Newcastle, Wyo.

	Feet.
Dakota:	
Sandstone, thin bedded	20
Sandstone, massive, reddish	30
Fuson:	
Shales and thin sandstones	15±
Lakota:	
Sandstone, buff, partly concealed	40±
Sandstone, massive, nearly white	45
Shale with coaly layers	6
Sandstone, gray to brown	20±
Morrison:	
Shale to bottom	90

These formations pass beneath the surface north of Newcastle, where the dip within a short distance changes from 3° to 22°. Plate I, *B*, shows the Dakota sandstone as exposed in a railroad cut north of Newcastle.

On the east side of the ridge, 2 miles south of Cambria, the bluff exposes the following section of the Lakota and associated formations:

Section on east side of ridge 2 miles south of Cambria, Wyo.

	Feet.
Dakota:	
Sandstone, rust colored, thin bedded at top and bottom	33
Fuson:	
Clay, massive, purple to maroon	17
Lakota:	
Sandstone, massive, dull gray above, yellowish tan color below	40
Shale, purplish, partly covered by talus	12
Sandstone, massive, salmon to brick red	60
Sandstone, massive, white	8
Bottom concealed by talus.	

On the west side of the ridge, opposite, many scattered outcrops of sandstones show considerable local variations in color. At one point a 5-foot coal bed is exposed. The following section sets forth the principal features:

Section on west side of ridge 2 miles south of Cambria, Wyo.

	Feet.
Dakota:	
Sandstone, light brown, mostly thin bedded	30
Fuson:	
Talus	35
Lakota:	
Sandstone, massive, salmon colored, conglomeratic at base	60
Talus, on sandstone in part	35
Sandstone, light gray to buff	35
Shale, gray	4
Sandstone, massive, brown	12
Coal and bone	1½
Sandstone, massive, brown	2
Coal, underlain by some sandstone	5
Morrison:	
Shales.	

Plum Creek.—On the west side of East Plum Creek a thickness of about 160 feet of massive light-colored sandstones shows local conglomeratic streaks and some intercalations of thinner-bedded members about 70 feet above the base. The details of a partly well-exposed section just north of Deford's ranch, 2 miles northwest of Cambria, are as follows:

Section on west side of East Plum Creek 2 miles northwest of Cambria, Wyo.

	Feet.
Dakota:	
Sandstone, massive, tan colored	20
Dakota(?) and Fuson:	
Sandstones, thin bedded, and shales of various colors	53
Lakota:	
Concealed	40
Sandstone, massive, pale pink to buff, conglomeratic at base	15
Sandstone, light buff, cross-bedded, conglomeratic at base	22
Unconformity (?).	
Sandstone, compact, pale pink to light gray	12
Sandstone, coarse, conglomeratic, brown	18
Sandstone, dark buff	24
Impure coal and coaly shale	6
Sandstone and shale	3
Coaly shale and thin coal beds	7
Sandstone, massive, tan colored	6
Shale, sandy, light gray	2
Sandstone, massive, buff	30
Concealed	15
Morrison:	
Shale	90+

In the canyon just southwest of Mount Zion ranch the Lakota and associated formations are as follows:

Section in canyon southwest of Mount Zion ranch, Wyoming.

	Feet.
Dakota:	
Sandstone, massive, light colored	30
Fuson:	
Sandstone and dark shales	20–30
Lakota:	
Sandstone, buff and tan colored, conglomeratic streaks	115
Coal, bony	½
Sandstone, hard	3
Coal	4
Sandstone with carbonaceous streaks	1
Coal	2
Sandstone, massive, partly cross-bedded, nearly white	40
Morrison:	
Shale, greenish.	

Oil Creek.—In Oil Creek and Blacktail canyons the Lakota varies in thickness from 125 to 160 feet. A typical section, including the Fuson and Dakota formations, on the west side of Oil Creek canyon 1½ miles below the mouth of Plum Creek has the following components:

Section on west side of Oil Creek canyon 1½ miles below mouth of Plum Creek, Wyo.

Dakota:	Feet.
Sandstone, massive, rust colored	40
Dakota?:	
Shale, sandy, gray	9
Sandstone, reddish	2
Fuson (in greater part):	
Sandstone, thin bedded, gray	1
Sandstone, dark pinkish	5
Sandstone, thin bedded, rust colored, with dark shale layers	25
Shale, gray	10
Sandstone, reddish	2
Shale, carbonaceous	1
Concealed	3
Sandstone, cross-bedded, gray	12
Concealed	15
Lakota:	
Sandstone, cross-bedded, massive, light colored (in part Fuson)	30
Sandstone, conglomeratic, light gray	25
Sandstone and coaly shale	2
Unconformity (?).	
Sandstone, massive, rust colored above, lighter below	19
Shale and sandstone, gray	20
Sandstone, massive, reddish tan to salmon colored	30
Morrison:	
Talus and shale	80

The cliffs on the west side of Oil Creek canyon above the mouth of Plum Creek exhibit the following section:

Section on west side of Oil Creek canyon 2 miles above mouth of Plum Creek, Wyo.

Dakota:	Feet.
Sandstone, massive, tan colored	55
Shale, sandy, gray	3
Sandstone, thin bedded, rust colored	24
Fuson and Lakota:	
Concealed	50
Lakota:	
Sandstone, massive, cross-bedded, gray	15
Sandstone, massive, cross-bedded, conglomeratic, tan to salmon colored	36
Sandstone, thin bedded, rust colored, with some shale	8
Shale, gray	1
Sandstone, massive, cross-bedded, tan colored	25
Shale, carbonaceous	½

Unconformity.

	Feet.
Sandstone, thin bedded, gray	6
Shale, purple	1½
Sandstone, massive, cross-bedded, light gray	24
Sandstone, massive, cross-bedded, rust-red colored	30
Morrison:	
Shale to Oil Creek	6

Owing to a local flattening of dips a short distance north, the lower sandstone descends to the water level and crosses the valley, but it rises again within a short distance, and 3 miles farther north it is more than 150 feet above the creek; however, its thickness is greatly diminished.

Although the above sections do not show the feature, the lowermost beds of the Lakota in some places are fine conglomerate or grit. This grit consists of closely compacted and well-rounded white, gray, black, pink, and red quartz, quartzite, and chert pebbles one-eighth inch in diameter in a matrix of white clay. It is well exposed at the coal openings in sec. 31, T. 48 N., R. 62 W., near the Holwell ranch, where the coal is underlain by a hard iron-bearing sandstone.

The variations in stratigraphy shown in the sections given above and the presence of a coal bed give the formation special interest. In the plateaus north of Newcastle the upper member of the Lakota is a massive sandstone of gray color usually about 90 feet thick and in places having conglomeratic streaks. The base of this member shows considerable evidence of local unconformity and in places contains a thin band of coaly shale. Next below is a massive, fine-grained, even-textured sandstone, commonly light ash-gray near the top but much darker below and locally rusty or tan colored throughout; it averages about 50 feet thick.

Under it is found the main coal horizon, which, with the thinner-bedded sandstones and shales underlying the coal, in some places attains a thickness of 25 feet. Where the coal is thin or absent its horizon is either immediately above the Morrison shale or an intervening thin layer of sandstone. Outside the Cambria basin the coal thins rapidly and merges into a carbonaceous shale that contains thin seams of coal. Along the west side of East Plum Creek the main coal horizon is represented by 12 or 14 feet of coaly shale containing scarcely any usable coal.

In the upper sandstone of the Lakota in the region west of Newcastle two pebble bands appear in most of the exposures. The upper is a small gray conglomerate layer in a massive tan-colored sandstone. The lower contains coarse rust-red pebbles scattered more or less thickly through a 10 to 12 foot bed lying about 30 feet above the coal horizon. Light tan-colored massive sandstone, varying in thickness but averaging about 20 feet, separates the two conglomeratic layers. The carbonaceous shale in the middle of the Lakota sandstone is well developed on Oil Creek and its branches, but it is of variable thickness and composition. It contains some thin coaly layers and has been prospected in places with the hope that it would prove to be an upper coal horizon.

Aladdin.—The Lakota sandstone is conspicuous on Hay Creek in the vicinity of Aladdin, where with the Dakota sandstone it makes prominent cliffs. It is somewhat thinner than at Cambria, averaging rather less than 150 feet. A section measured by Prof. Jenney is as follows:

Section of Lakota sandstone at Aladdin, Wyo.

Fuson shale.	Feet.
Sandstone, massive, yellow, cross-bedded; forming cliffs	35
Conglomerate; small pebbles of flint and quartz	3
Breccia; angular fragments of sandstone and shale in white clay	3–10
Sandstone, yellow	10
Sandstone, massive, gray, thin layers; forming cliffs	30
Shale, drab, clay, with plant remains	2–5
Shale, soft, sandy, with carbonized plants	2
Coal	1
Sandstone, soft yellow	4
Shale, drab, clay	12
Coal	3
Shale, drab, clay (Morrison?).	
	115

Sections measured at two or three places west and south of Aladdin show the Lakota somewhat thicker.

The Lakota sandstone is well exposed in all the canyons north of Edgemont, S. Dak. Cheyenne River cuts a canyon through it at the anticline about 4 miles east of the town, revealing this section:

Section of Lakota sandstone 4 miles east of Edgemont, S. Dak.

	Feet.
Sandstone, massive, fine-grained, white	100
Sandstone, slabby, and shale	40
Sandstone, massive, fine grained, light gray	40
Sandstone, shaly and thin bedded	10
Sandstone, massive, white to dirty gray	230
	420

In deep well borings at Edgomont this sandstone was recorded as 222 feet thick.

FUSON SHALE.

A band of shale and thin-bedded sandstones lying between the massive Lakota and Dakota sandstones is known as the Fuson shale. Its thickness ranges from 10 to 100 feet. Because of its position between massive sandstones, it is commonly obscured by talus. The pink, red, maroon, gray, and buff shales give the formation a readily distinguishable character. On the west side of Oil Creek, near the T E ranch, the formation consists of 20 feet of dark-gray shale and sandy shale overlain by 6 feet of thin-bedded buff sandstone. On Mason Creek, in secs. 5 and 6, T. 48 N., R. 62 W., bands of carbonaceous shale a few inches thick, have been found in the formation. Although the outcrop is commonly hidden, some good exposures can be found in the steep cliffs.

At the north end of the Black Hills the Fuson is reported to be a little thicker than on Mason Creek. On the south fork of Hay Creek at Aladdin the following section was measured by Prof. Jenney:

Section of Fuson shale at Aladdin, Wyo.

	Feet.
Dakota sandstone.	
Talus	15
Sandstone, yellow-brown	5
Talus	12
Sandstone, yellow-brown	6
Clay, purple, partly exposed	20
Sandstone, yellow, thin bedded	15
Lakota sandstone, massive.	
	73

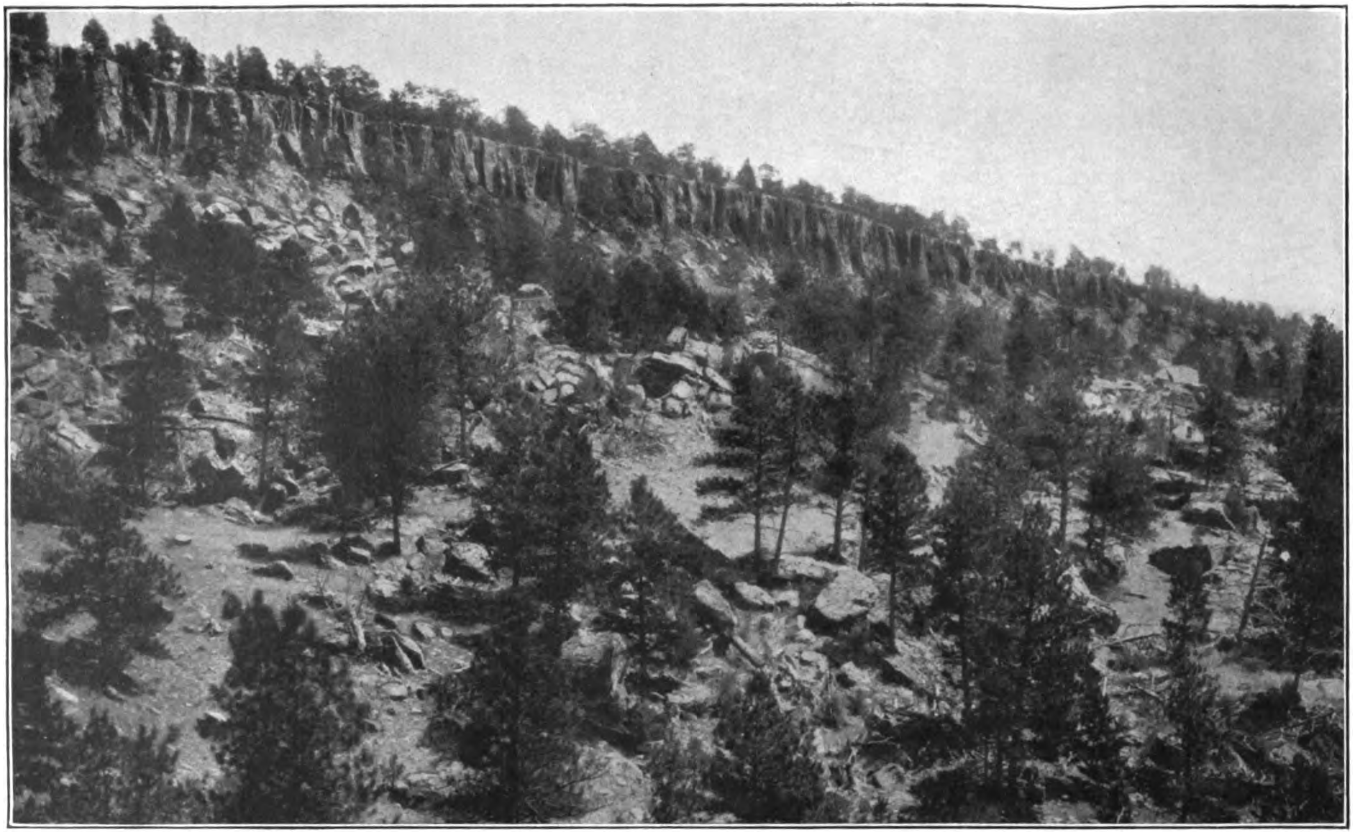
Half a mile west the formation appears to be 102 feet thick, whereas a mile south of the south side of the ridge it is 70 feet.

Well-preserved fossil leaves found in the base of the shale in the vicinity of Aladdin place these beds in the Lower Cretaceous.

DAKOTA SANDSTONE.

The Dakota is a coarse-grained buff-colored sandstone ordinarily from 140 to 150 feet thick, which forms the upper and outer surface of much of the outer rim of the Black Hills. It is described above (pp. 9–13) in connection with the Lakota sandstone. The Dakota sandstone is often massively bedded and cross-bedded, merging into a thin-bedded variety in the upper portion. Reddish color is characteristic of the massive lower, cliff-forming member, from which the rock breaks off in great vertical slabs or rude columns. (See Pl. II.) This massive character is lacking in some localities, especially north of Newcastle, where the formation is softer or thinner bedded.

An exceptional phase of the formation is exposed in the canyon of Little Oil Creek just above Newcastle, where it is represented by a series of alternating, mostly thin-bedded sandstones and shales of dark color. As the Fuson shale is less distinctive here than usual it is difficult to recognize the precise dividing line between the two formations. On the branches of Plum Creek the Dakota has been extensively eroded, but small outliers remain on the summits of some



TYPICAL CLIFFS AND TALUS OF MASSIVE DAKOTA SANDSTONE.

of the adjoining ridges. Its identity is in some places doubtful. In the region north of Newcastle there is a general thinning of the formations to the north and northeast. On the high tables about Cambria the thickness varies from 40 to 60 feet, the massive lower bed occurring in the thicker portions.

The broad table-land about Mount Zion ranch owes its character to the underlying Dakota sandstone, as does also the west-sloping surface between Oil and Skull creeks. Northwest of Cambria only the highest parts of the narrow ridges are capped by Dakota sandstone, but in the vicinity of Ezra the Dakota underlies and causes the altitude of the westward slope of the triangular area between Mason, Dry, and Skull creeks. North of Mason Creek the Dakota sandstone caps the plateau in the east part of T. 49 N., R. 64 W., and is found in small patches on the highest parts of the hills between Inyankara Mountain and Sheldon. It also caps the ridge between the middle and south forks of Hay Creek at Aladdin, Wyo., and forms the broad south-facing slope north of Edgemont, S. Dak. In deep wells at Edgemont the Dakota seems to be 55 feet thick.

Considerable iron in the Dakota sandstone gives rise to the reddish-brown color of the weathered rock. Much of the iron is in the form of small ironstone concretions and sand cemented by iron oxide. Fossil plants collected in it show that the age of the Dakota sandstone is Upper Cretaceous.

GRANEROS SHALE.

The youngest formation to be mentioned in connection with the stratigraphy of the coal is a fissile shale about 1,000 feet thick which rests directly on the Dakota sandstone and is known as the Graneros shale. It is mostly dark colored and makes gumbo soil. Within about 200 feet of its base the formation contains a conspicuous band of hard shale and thin-bedded fine-grained sandstone which weathers light gray and owing to its hardness forms a line of knobs and ridges that rise slightly above the main clay slope. This is an extension of the Mowry shale member of the Bighorn Mountains and adjacent regions, and like the Mowry is full of fish scales. Except for these the Graneros shale contains few fossils. Its age is lower Benton.

COAL.

INTRODUCTION.

The coal beds found at a number of places around the Black Hills in South Dakota and Wyoming are at or near the base of the Lakota sandstone. The talus of great blocks of sandstone which accumulates on the Lakota-Morrison contact and the generally wooded condition of the slopes conceal the coal and makes finding it difficult. Natural exposures of the horizon are few, and where they do occur the coal may have weathered or burned out and the overlying sandstone have come down.

It is believed that the Lakota coal beds are commonly lenticular and that aside from the deposits at Cambria they cover no great area. In some places only one bed of coal occurs, but in a number of others a second and smaller bed is found a few feet higher in the section.

The coal of the Black Hills in its best development is a bituminous coking grade, but it varies from place to place and in different benches of the same bed. Besides coking coal, noncoking bituminous, cannel, splint, and "pine-needle" coal are found. (See pp. 49-50.)

OCCURRENCE.

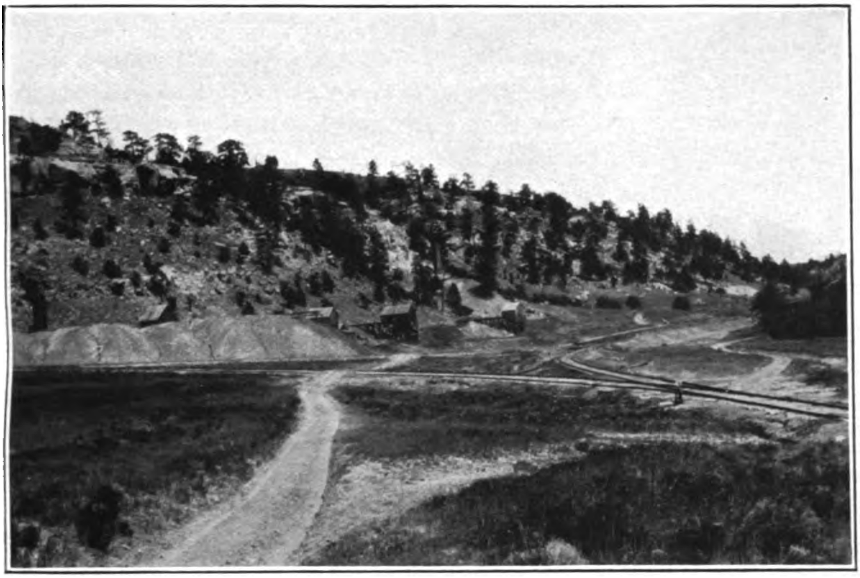
The coal localities in the Black Hills will be described in order along the west side of the hills, beginning with the northernmost at Aladdin and concluding with those east of Edgemont, S. Dak.

ALADDIN.

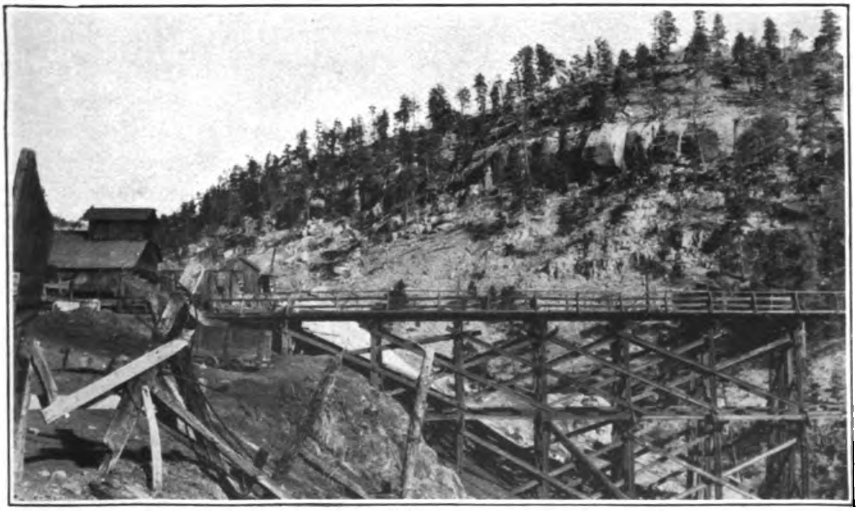
Coal was discovered at the north end of the Black Hills on Hay Creek about 1875–1880. It was mined by the early settlers, who for protection against the Indians lived in a stockade near the site of the present store at Aladdin, Wyo. The coal is in two beds in the lower part of the Lakota sandstone. The main bed is from 3 to 6 feet thick where it has been mined, and the upper bed is about 2 feet thick. The beds are separated by 10 to 20 feet of sandy shale. The outcrop along the north side of the creek has been thoroughly prospected for a distance of 2 miles. West of the store four prospect drifts driven at the horizon of the coal bed failed to find coal. One of them at the west side of sec. 28, T. 54 N., R. 61 W., is said to have been 300 feet long. The writer could not verify the absence of coal in this drift, which is caved and inaccessible, except by the fact that there is none on the dump. A few rods farther west 1 foot of black shale is exposed at this horizon. (See fig. 2.)

Within one-half mile east of the store, along the base of the bluff north of the railroad, seven entries and prospects have been driven on the coal bed. All are now caved so that the coal bed can not be seen. The dumps, mine tracks, and cable used for hauling trips out of the mine show that a workable coal bed must have been found here; it is said to be 5 feet thick, but the complete abandonment suggests either that the bed was of workable thickness only over a small area or else that the coal was not of satisfactory quality.

About a mile east of Aladdin, or near the center of sec. 27, T. 54, N., R. 61 W., several openings have been made on the coal. The first,



A. STILWELL COAL CO.'S MINE AND LAKOTA SANDSTONE AT ALADDIN, WYO.



B. LAKOTA SANDSTONE IN CAMP CANYON NEAR CAMBRIA, WYO.

marked by an air stack, is caved full, but shows coal on the dump. The next, at the head of the railroad Y, is caved at 40 feet and only the top of the coal bed is exposed. An air course and entry at the same point is open for 200 feet, but is supported by square sets and lagged so tight that the coal bed is completely hidden.

The only mine now open at Aladdin is a mile east of the store, on the east side of the railroad Y. (See Pl. III, *A*.) The main entry was driven north down the dip for 1,350 feet and a few rooms were opened. Pillars have been drawn from the inner part of the mine and the entry is caved full at about 700 feet from the surface. In this distance two small faults having an east-west course displace the coal bed to a maximum extent of about 15 feet. They may be due to the breaking down of the valley wall or cliff formed by the massive sandstones. The coal bed in the 700 feet of drift now accessible ranges in thickness from 18 inches to nearly 4 feet. At the working face, about 700 feet from the mouth, where a section was measured and sample taken, the bed is 46 inches thick (see Pl. IV, fig. 1, p. 34) and is distinctly divisible into two parts. The upper half of the bed is a bright bituminous coal, possibly adapted to blacksmithing, and the lower half is hard, dull, and bony, with sulphur and iron bands. This lower bench mines in hard blocks, whereas the coal of the upper bench crumbles readily. In the summer of 1909, when the writer visited Aladdin, coal was being mined here every few days for use in a locomotive.

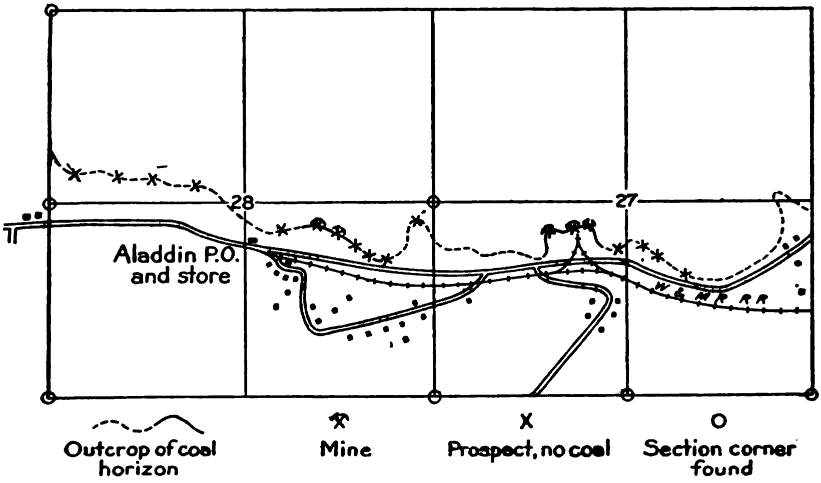


FIGURE 2.—Sketch map of mines and prospects near Aladdin, Wyo.

The run-of-mine coal examined at the tipple is composed of small pieces of pitch-black, clean, glossy bituminous coal of good appearance, and of blocks or large lumps of hard, ashy coal. These lumps, which form a considerable part of the output, contain thin bands of mineral charcoal, streaks of brown carbonaceous dirt, thin bands of clean, bright coal, and nuts of sulphurous clay and iron pyrite. In some of these dull lumps the bands or lamellæ of bright coal appear to be set on edge in carbonaceous shale, and as a result some of the faces of these lumps have a rough, pointed, or hackly fracture. In some places a thin band of irregularly disposed carbonized fibers, which can be ignited individually with a match and will burn freely, is found in the coal.

Analyses of the Aladdin coal will be found in the table on pages 54–55. They include two samples of the whole bed (1976, 1977), one each of the upper and lower half (9320 and 9321, respectively), and a car sample (2278).

A few rods east of the working mine an entry and air shaft is caved full; also an entry of some size, square timbered, and lagged tight, so that the bed is not visible. This entry is caved full at 150 feet from the mouth and there is no coal on the dump. An entry driven on the upper bed at this point is inaccessible. Probably the coal is not thick enough to be considered workable under present conditions, as it is said to be nowhere more than 2½ feet thick and in most places less.

In the Aladdin folio[1] Darton states that two of the openings at Aladdin were driven northward nearly one-fourth of a mile along the coal. He says that numerous prospect holes in the vicinity show beds of pure coal which, in most portions of the area, are a foot or less in thickness. Little prospecting has been done outside the valley of Hay Creek.

Activity in coal mining was greatest from 1898 to 1902, when from 150 to 200 men were employed. Shipments in 1902 amounted to about 10,000 long tons of soft bituminous coal suitable for locomotive and domestic use. The output in 1909 was about 60 tons per month, or enough to supply the single locomotive of the narrow-gage Wyoming & Missouri River Railroad, which connects Aladdin with the Chicago & Northwestern Railway at Belle Fourche, S. Dak.

Further evidence of the character of the Lakota coal beds is had from North Fork of Hay Creek. According to Prof. Jenney[2] coal prospects consisting of a drift run into the hillside about 60 feet and two shafts sunk to a depth of 90 feet, 1½ and 2 miles north of The Forks, show four beds of coal, none of which is over 1 foot thick. The relations and thicknesses of these coal beds are as given in the following section, which is combined from sections measured at a tunnel and a shaft one-half mile apart:

---

[1] Darton, N. H., Aladdin folio (No. 128), Geol. Atlas U. S., U. S. Geol. Survey, 1905, p. 8.

[2] Jenney, W. P., Field observations in the Hay Creek coal field; Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, pp. 584–585.

Section of Lakota coal beds on North Fork of Hay Creek.

	Feet.
Sandstone, gray, coarse	5
Sandstone, yellow, massive, cross-bedded	30
Sandstone, yellow, massive, soft, thin bedded	40
Coal, impure and shaly, at tunnel	½–¾
Shales, drab clay	20
Coal, shaly	1
Sandstone	1
Shale and sandstone, alternating	12
Coal	½
Shale, black	2
Sandstone	3
Coal and shale	1
Clay	3
Clay shale, black, changing to gray shale at base	12
Sand rock	2
Shale with fossil, plants	2½
Sand rock	6
Morrison clay.	
	143

This shows that the coal bed workable at Aladdin does not maintain its thickness in this direction and furnishes confirmatory evidence that the Lakota coal beds were deposited in local basins and are lenticular in outline.

SUNDANCE.

Coal has been found at a number of places in the ridges west of Sundance. The nearest occurrence, 4 miles west of the village, is in a narrow isolated ridge in the west part of T. 51 N., R. 63 W. Lakota sandstone caps the southern end of the ridge. At the southeast corner a drift is said to be on a coal bed about 6 inches thick. It is reported that the drift is about 100 feet long, and was abandoned because the coal did not increase in thickness.

In a flat-topped butte or table 6 miles west of Sundance, in sec. 24, T. 51 N., R. 64 W., four drifts have been driven on the coal. (See fig. 3.) The first, on the east side of the butte, is reported to have been driven 450 feet by Albert Mann, but it is caved now and is accessible for about 20 feet only. The coal, under thick cover, is said to be 4 feet thick, but not of high grade. A section measured by the writer at the mouth of the drift shows a roof of soft drab shale; an upper bench, ranging from 1 to 2 feet thick, composed of a fair bituminous coal streaked with sandstone and bone; 4 to 6 inches of soft drab clay; and a lower bench of fair bituminous coal 1 foot thick, but in part bony.

Directly opposite, on the west side of the hill, in the NE. ¼ NW. ¼ sec. 24, a drift, driven by John Belsher between 1895 and 1900, is now caved and inaccessible. It is reported that this drift went about 450 feet in a southeast direction and showed approximately 4 feet of coal. A second drift, on the west side of the hill in the NW. ¼ NW. ¼ sec. 24, was started by Ernest Bolton in the spring of 1909, and at the time of the writer's visit early in July of that year it had been driven about 100 feet. The roof is hard drab clay shale and the floor is hard sandy shale. The coal is in two benches, the upper one 17 inches and the lower one 20 inches thick, separated by 5 inches of clay. It is a fair-grade bituminous coal and, where seen, is only in part bony in the lower bench.

The fourth opening, made by Ernest Bolton in the fall of 1908, is at the south end of the hill, in the SE. ¼ NW. ¼ sec. 24. In 1909 this drift had been driven about 125 feet north, down a slight dip on the coal; it contained about 2 feet of water at the face. A slope had been started at a lower level for drainage and an easier grade for bringing out loaded cars. About 30 feet from the entry the bed has a thickness of 2 feet 4 inches and is composed of carbonaceous shale and bone with 6 inches of good bituminous coal near the middle. Mr. Bolton says that at the face of the drift the bed shows nearly 4 feet of good coal. Bony coal appears on the dump. From 50 to 75 tons of this coal were sold in Sundance in the winter of 1908–9, but the people who used it say the percentage of ash is very high.

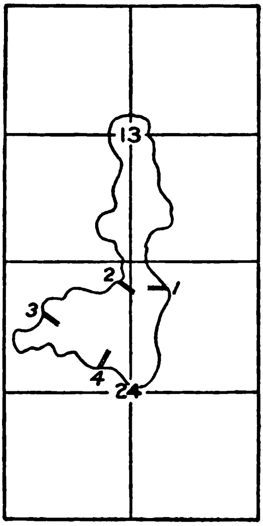


FIGURE 3.—Coal area in secs. 13 and 24, T. 51 N., R. 64 W.

The best bed of coal seen by the writer in the Sundance region is about 10 miles southwest of the town on Coal Divide. It is reached from the Rogers ranch on the Moorcroft road in sec. 10, T. 50 N., R. 64 W., by a dim road leading south across the meadow about one-half mile to a point on the rim rock and thence down to the base of the Lakota sandstone and to an old, abandoned, and inaccessible prospect on the coal. One hundred yards farther west is a drift which was opened in the winter of 1908–9 by Steve Pyles and Ole Olson and driven about 50 feet with a crooked course. The roof of the coal bed is thin-bedded hard drab shale, and the floor is 5 inches of hard sandstone underlain by soft clay shale. Four feet of coal is found here in a bed divisible into three benches. The upper bench is 2 feet of splint with streaks of fine coal; the middle is from 10 to 12 inches of fine bright bituminous coal; and the lower is 1 foot of splint or bony coal with thin bands of shale. (See Pl. IV, fig. 4.) This coal, like all that in the Sundance region, is high in ash, and can not be classed as a high-grade domestic fuel. Darton[1] mentions a tunnel 650 feet long in the SW. ¼ sec. 11, T. 50 N., R. 64 W., and another tunnel, not in use, in sec. 10, on the opposite side of the canyon. This seems to be the same locality as the coal bank opened by Pyles & Olson and may refer to the two openings already described. As this is the only place in several miles where coal has been found it can not be stated whether the broad flat-topped ridge known as Coal Divide is underlain by coal or not. Considering the lenticular character

---

[1] Darton, N. H., The coal of the Black Hills, Wyoming: Bull. U. S. Geol. Survey No. 260, 1905, p. 433.

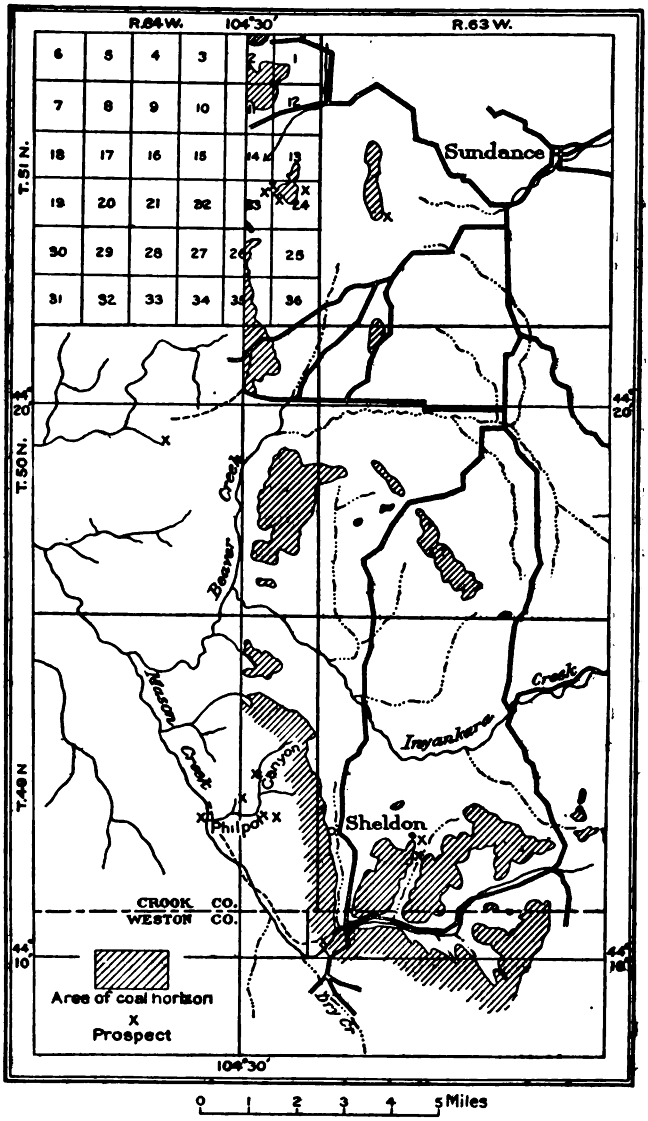


FIGURE 4.—Map showing location of Sundance and Mason Creek prospects.

of the Lakota coal beds in other places around the Black Hills it is surmised that the extent of the bed here is small. This, however, can be determined only by further prospecting along the outcrop and by drilling from the plateau above.

MASON CREEK.

RIDGE WEST OF INYANKARA MOUNTAIN.

Near Sheldon post office on Mason Creek, 16 miles northeast of the Chicago, Burlington & Quincy Railroad at Upton, there are several exposures and prospects on the Lakota coal. Of one of these at the western end of a ridge 3 miles west of Inyankara Mountain, in sec. 22, T. 49 N., R. 63 W., Darton[1] says: "On the ridge west of Inyankara Mountain it is reported that the coal deposit near the base of the Lakota formation has a thickness of 9 feet, including a number of layers of shale and bone." This same locality was reported to the writer by a resident of the district as showing a considerable thickness of workable coal, but examination showed that the supposed coal consisted of 9 feet of black and brown carbonaceous shale containing one or two bands of coal less than one inch thick. Near the eastern end of the same ridge, in a saddle which cuts through to the Morrison shale, the coal horizon is marked by less than a foot of carbonaceous shale.

On the southern end of this isolated block of Lakota sandstone the contact between the Lakota and Morrison formations was closely examined at two or three points where the exposures are good, but no trace of coal could be found. The same is true of the block of Lakota lying in secs. 29 and 32, T. 49 N., R. 63 W. The horizon was prospected at two or three points (see fig. 4), but only a few inches of dark shale could be found.

MILLER COAL MINE.

A small knoll, 2 or 3 acres in extent, on the eastern boundary of sec. 29, T. 49 N., R. 63 W., is underlain by coal. This is shown by three small prospects in which from 1 to 2 feet of coal is exposed and by a small mine on the south side of the knoll, opened and operated by Charles H. Miller, of Sheldon, to supply neighboring ranches. According to Miller an entry driven 140 feet into the hill passed through horsebacks or rolls in the coal bed at intervals of about 30 feet. This entry has been "gobbed" full and a new one turned to the right for a distance of 40 feet. At the head of this second entry the coal bed is about 4 feet thick, but it is almost entirely cut out on the left by a roll and 20 feet away by another. The section at the head of this drift is as follows:

---

[1] Sundance folio (No. 127), Geol. Atlas U. S., U. S. Geol. Survey, 1905.

Section of Lakota coal bed at Miller mine, sec. 29, T. 49 N., R. 63 W.

	Ft.	in.
Roof, black sandy clay.		
Shale, black with fine seams of pyrite		3
Coal, cannel, solid	1	8
Shale, black		9
Coal, cannel, solid		9
Cleavage line.		
Coal, cannel and bone, in 2 to 4 inch bands	1	4
Coal, bituminous		4
Clay, black, shaly	3	
Total coal	4	8

Although this section has sufficient thickness, the numerous rolls and the small area make the bed of little value, except as here used to supply a very few customers. The cannel coal in the above section breaks with smooth cleavage faces and has the characteristic velvety luster. It burns readily, but carries 23 per cent of ash. (See analysis No. 10410, p. 55.) The 4 inches of bituminous coal at the bottom of the bed somewhat resembles ordinary eastern soft coal, being composed of bright and dull bands one-eighth to one-fourth inch thick. It is reported that in a prospect directly opposite this mine on the spur to the south still less coal was found. The prospect is caved, so the report was not verified, but half a mile farther south in the NE. ¼ SE. ¼ sec. 29, an old prospect was reopened and no trace of coal could be found, the bed being represented by carbonaceous clay. The following section was measured:

Section at prospect near Miller coal mine.

	Ft.	in.
Sand and sandstone, grayish yellow, thin bedded	1	10
Clay, bluish gray, with ferruginous seams	1	9
Shale, brown, woody		1
Clay, dark, carbonaceous	1	10
Clay, bluish gray	1	
Clay, dark, carbonaceous	2	

About one-fourth mile south of this prospect Morrison shale is overlain by Lakota sandstone with about 3 inches of brown carbonaceous shale at the contact.

PHILPOTT CANYON.

In the hope of discovering a better coal, Charles H. Miller has opened several prospects on or near Philpott Canyon, which empties into Mason Creek about 3 miles below Dry Creek. These are on the Lakota bed and reveal the characters already described. One of these prospects, near the head of Philpott Canyon a mile above its mouth, probably in the SW. ¼ NE. ¼ sec. 23, T. 49 N., R. 64 W., is in the west bank 50 feet from the stream in the edge of timber one-half mile below the J. B. Roche homestead claim. The drift, which has been driven 10 or 12 feet through soil to bedrock, shows a bright black, flaky, dirty coal, as follows:

Section in upper Philpott Canyon.

	Ft.	in.
Sandstone, Lakota		
Clay, drab and brown	6	
Coal, dirty, flaky, bituminous ?	1	7
Shale, carbonaceous; weathers brown	1	8
Shale, floor.		

A few streaks of bright coal appear in the lower part of the 20 inches of brown shale. Nothing about the prospect suggests that the coal will be thicker under the hill.

Farther down Philpott Canyon in the second small draw above the mouth, on the north under a sandstone ledge, two coaly bands are separated by 18 inches of sandstone. The upper band is 1 foot thick and the lower one 20 inches to 2 feet thick. Both appear to be a mixture of black clay and pressed mineral charcoal and also differ from the true Lakota coal in that they soil the hands very markedly. Not only are these bands too thin to be worked but also they are apparently not true coal.

On another branch of Philpott Canyon, the following section was measured at a small prospect in the Fuson shale:

Section at prospect in Philpott Canyon.

	Ft.	in.
Sandstone, carbonaceous, with ¼-inch seams of coal and nodular ferruginous layers	1	10
Clay, gray		10
Sandstone, argillaceous, yellow and gray	1	10
Shale, sandy to sandstone, argillaceous	1	8
Shale, slaty gray		3
Coal, bony at bottom		9
Shale, carbonaceous, with ¼-inch streaks of coal	1	7
Clay, gray		1
Shale.		

The largest prospect in the vicinity is 15 feet above water in the west bank of Mason Creek opposite the mouth of Philpott Canyon, 3 miles below Dry Creek. It is driven west about 15 feet under massive Lakota sandstone.

Section at prospect on Mason Creek opposite Philpott Canyon.

	Ft.	In.
Sandstone, buff, massive; a ledge maker	15	
Sandstone, white, shaly	3	
Clay, white		6
Coal, flaky, dirty; resembling charcoal	1	6
Clay, dark drab with carbonaceous flakes		3
Clay, white with carbonized roots	4	9
Coal, flaky, dull, square cleavage; resembling charcoal	1	1
Shale, black, carbonaceous	1	
Shale, dark	3	
Sandstone.		

It is apparent from the foregoing section that although there is sufficient coal here to raise the hopes of the prospector, there is little to encourage development.

DRY CREEK.

The energy that may be expended on a small showing is illustrated by a prospect in the bank of Mason Creek, just above the mouth of Dry Creek, where a drift 80 feet long and well timbered at the mouth has been driven on a thin bed of carbonaceous shale. The section is given below:

Section at prospect near mouth of Dry Creek.

	Ft.	In.
Shale, sandy, with sandstone layers	3	
Sandstone, ferruginous	1	1
Sandstone, argillaceous, iron stained	5	8
Shale, drab	1	11
Sandstone, gray, ½-inch concretionary iron bands near base	3	9
Clay, sandy		9
Sand, gray		6
Sand and clay		7
Clay, gray		11
Sandstone, yellowish, thin bedded	1	
Shale, carbonaceous, hard and brittle, with lenses of gray clay		4–10
Clay, streaked white and gray		7
Shale, clayey, black, carbonaceous		11
Clay, light gray		6

This section is in the Fuson shale, which in this vicinity carries carbonaceous shale beds and in places a little coal.

SKULL CREEK.

In T. 48 N., R. 63 W., the writer did not find any trace of coal. The horizon was examined in the detached block northwest of the Holwell ranch and on the road crossing the escarpment between

Ezra and Holwell's, but without success. It is reported by W. E. Holwell that some years ago a shaft and drill holes were sunk to the coal horizon from the top of the table in section 22, but that no coal over a foot thick could be found.

Lakota coal of workable thickness occurs in the vicinity of the Holwell ranch on Skull Creek, about 30 miles northwest of Newcastle, and has been opened by drifts at three or four places. That this increased thickness is local, however, is shown by prospects and outcrops in the immediate vicinity which do not disclose coal. The main openings on this coal are 1½ miles southeast of the Holwell ranch, in the SE. ¼ SE. ¼ sec. 31, T. 48 N., R. 62 W. (See fig. 5.)

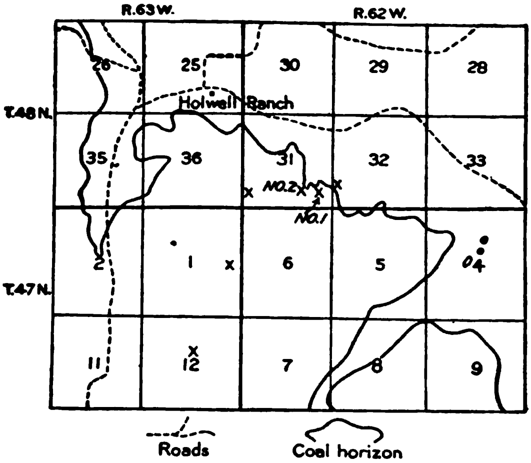


FIGURE 5.—Sketch map showing location of prospects at Holwell ranch, northwest of Newcastle, Wyo.

At the heads of two ravines in the woods on the steep bluff formed by the massive Lakota sandstone there are two drifts about 500 feet apart. The easternmost, or Holwell No. 1, has been driven south 55 feet. The rocks at this point dip southwest about 2°. From the surface to the breast the thickness of the coal bed increases about a foot. The section of the coal at the face of the drift is as follows:

Section at Holwell coal bank No. 1.

	Ft.	in.
Sandstone roof.		
Clay, drab, soft.		
Bone (analysis 6744, p. 54)	1	2
Coal, bituminous, with ashy and bright streaks	2	
Coal, bituminous, bright (analysis 6746, p. 54)		7
Coal, cannel (analysis 6743, p. 54)	1	6
Coal, bituminous, bright (analysis 6746, p. 54)	1	9
Coal, cannel	1	4
Coal, bony, shaly; burns well		8
Sandstone.		
	9	

A section at the Holwell No. 2, about 500 feet farther west, shows a decreased thickness in the bed and is as follows:

Section at Holwell coal bank No. 2.

	Ft.	in.
Bone		6
Bone, with streaks of bituminous coal	1	1
Coal, bright, bituminous		3
Coal, bony		8½
Coal, bright, bituminous		2½
Coal, bituminous, dull		5½
Coal, cannel		5
Coal, bony		1½
Coal, bright, bituminous		9
Coal, splint	1	
Bone		6
	6	

Analysis 6745, p. 53, is from a sample taken in this prospect. The drift at this second bank was driven south 55 feet and then turned southeast 40 feet. It is timbered and lagged tight to hold the soft clay roof. The floor is hard, flinty ironstone resting on massive white sandstone.

Both drifts are dry and are in good condition for examination. Very steep wagon trails lead to both of these drifts, but that to No. 1 has been so long abandoned that it is overgrown with brush and partly obliterated by talus. Analyses (see p. 54) have been made of samples taken from the whole bed at each of these two openings and separate analyses of the cannel, bone, and best coal at Holwell No. 1.

About 1,000 feet east of Holwell No. 1, close to the line between secs. 31 and 32 and a little south of the east quarter-section stone in the timber on the steep hillside, a small prospect, opened directly under the Lakota sandstone, revealed the following section:

Section 1,000 feet east of Holwell No. 1.

	Ft.	in.
Clay, drab, and shale, brown	1	
Coal, ashy, with bituminous streaks		10
Sandstone, white, soft, with streaks of carbon		5
Coal, bituminous, good quality	2	4
Quartzite, gray, mottled with white.		
	4	7

No trace of coal has as yet been discovered east of this small prospect or west of Holwell No. 2. In fact, at the point of the spur over which a wagon road leads from Holwell's ranch to the tableland, and close to the range line at the northwest corner of sec. 31, the horizon is well exposed and shows several feet of black and brown shale without coal.

It is reported by Mr. Holwell that two churn drill holes put down by his sons in sec. 36, T. 48 N., R. 63 W., found only a little black mud at the coal horizon, and that a shaft near the southeast corner of the same section went through the Lakota sandstone into the Morrison shale without finding coal.

A shaft sunk at the east quarter corner of sec. 1, T. 47 N., R. 63 W., in the summer of 1908 by Mr. George S. Jackson, of Deadwood, S. Dak., is at the base of a spur at the head of the middle fork of a small stream which flows west through section 1. The shaft is 6 feet square, timbered, and passes through 59 feet of Lakota sandstone. In hopes of finding the Lakota coal, it was continued below the sandstone for nearly 50 feet. The only trace of coal, however, was from 9 to 15 feet below the sandstone, where nodules of iron pyrite were found, carrying fragments of coal. These two shafts and two drill holes indicate the nonoccurrence of the Lakota coal in this vicinity.

Coal is present, however, near the center of sec. 12, T. 47 N., R. 63 W., and is exposed in the bed of a ravine. Two drifts have been opened, one in the north and one in the south bank. These are on land patented by J. C. Spencer, and will be called the Spencer prospects. The drift in the north bank is only 10 feet long and shows the following section:

Section at Spencer prospect, north bank.

	Ft.	In.
Shale, brown to black; changing to shaly sandstone	4	
Cannel, glossy below, dull above, upper half platy, lower half closely checked	1	2
Shale, brown, carbonaceous		3
Coal, bituminous		1
Shale, brown, carbonaceous		4
Coal, bituminous, fair quality		4
Bone, deep weathered with laminæ of bituminous coal	1	1
Ironstone floor.		
Total coal bed	3	3

The drift in the south bank has been driven south 110 feet, and discloses the section here given:

Section at Spencer prospect, south bank.

	Ft.	In.
Shale, brown to black	4	
Coal, splint		9
Coal, splint, very ashy		3
Bone		11–14
Coal, bituminous with pyrite nodules	2	2
Ironstone floor.		
Total coal bed	4 to 4	1 4

A shaft sunk to the coal horizon a few rods north of the Spencer prospects found the bed diminished in thickness. At an abandoned and partly-filled shaft a few hundred yards up the ravine there is nothing on the dump to indicate that coal was found. An examination of the outcrop in Black Canyon and on Oil Creek, both by the writer and by prospectors during the past 20 years, has failed to discover any point where this coal bed is over a foot thick.

This evidence as to the occurrence of coal in the vicinity of the Holwell ranch suggests that, although the coal bed is of workable thickness at two or three places, this character probably continues only a short distance. The development of a mine here should be preceded by thorough drilling to find the extent of the coal.

PLUM CREEK.

The outcrop of the Lakota sandstone on both branches of Plum Creek has been prospected for coal during the past 15 years, practically without success. So far as known the only showings of coal are in two prospects near the head of East Plum Creek. One of these, at the head of the fork in sec. 18, T. 46 N., R. 61 W., is as follows:

Section of coal bed on East Plum Creek.

	Ft.	in.
Shale, carbonaceous		8
Coal		8
Sandstone	1	
Coal, dirty, containing sand	1	8
Coal, slightly sandy		5½
Sand, with 1-inch lenses of coal	2	2
	6	7½

This coal appears to be of too poor quality for mining.

On the opposite side of the stream in sec. 12, T. 46 N., R. 62 W., another exposure of this bed shows the following section:

Section of coal bed on East Plum Creek.

	Ft.	in.
Coal, impure		8
Coal, good		7½
Coal, bony		10
Coal		6
Shale, sandy	1	4
Coal		2½
Coal, bony	1	1
	5	3

The bed is thick enough to mine, but only a small part is good coal.

Openings made at the base of the massive sandstone below the forks of Plum Creek do not show any coal. The coal horizon is rarely exposed because of the heavy talus from the overlying sandstone, but at the few natural exposures examined by the writer the coal was not found. Not only is this true of the canyons cut in the plateau, but also of the escarpment on the west of Salt Creek. Here the coal horizon is almost completely hidden and but one exposure was seen. This is in the N. ½ sec. 17, T. 46 N., R. 61 W., and shows a thin bed, possibly an upper one above the main Lakota coal bed.

Section of coal bed west of Salt Creek, near Salt Spring.

	Ft.	in.
Bone, shaly		5
Coal		5
Coal, bony or cannel		6
Coal		3
	1	7

If this is a complete section of the bed mined at Cambria, it shows that the limit of workable coal is not so far north as mapped in the Newcastle folio (No. 107), and suggests the possible absence of the coal in the Northwest Table and in Sweetwater Mountain.

It can not be said that there is no coal in the ridges between Black Canyon and the head of Salt Creek, but none of any value has been found in 30 years. The only indication in this part of the field is a 4-foot bed of black, coaly shale discovered by the writer in a landslip about 1½ miles southeast of the T E ranch. The weathered outcrop did not permit an exact determination of the character of the material, but it did not appear to be good coal. An effort to find the bed in place was unsuccessful.

CAMBRIA.

HISTORY.

The discovery of coal in the vicinity of Cambria is variously reported at dates ranging from 1877 to 1886. The field was first thoroughly prospected in 1886, and discoveries made which called attention to the possibilities of the Black Hills as a source of fuel for a railroad crossing the northeast corner of Wyoming. The Burlington & Missouri River Railroad, which was then completed to Grand Island, Nebr., offered to build on west across Wyoming if a sufficient supply of coal could be had.

Kilpatrick Bros., of Beatrice, Nebr., tested the field at Cambria with diamond drills and started entries in 1889. The main line of the Burlington was extended into Wyoming, with a spur from Newcastle to Cambria, and the first car of coal was loaded in December, 1889, in which month 2,700 tons were shipped.

The mines were opened by Kilpatrick Bros. & Collins and operated by them under the name of the Cambria Mining Co. until December 31, 1902, when possession was transferred to the Cambria Coal Mining Co., which carried on operations during 1903. In February, 1904, the property went back to the original owners, who reincorporated as the Cambria Fuel Co. and are the present owners of the property.

Cambria is the only place in the Black Hills where the Lakota coal has proved of workable thickness over more than a few acres. Here it is workable through a considerable part of 12 square miles. Extensive mines are operated by the Cambria Fuel Co., the only producers and shippers in the Black Hills.

MINES AND METHOD OF MINING.

The coal near Cambria lies practically flat 200 to 300 feet below the surface of a plateau, which is deeply dissected by Camp and Coal canyons and their branches. It outcrops in the canyon walls 50 or 60 feet above the bottoms so that the mines have plenty of tipple and waste room. The coal bed in the Cambria mines varies normally from 3 to 10 feet in thickness, has a hard sandstone roof and floor, and is free from gas and water.

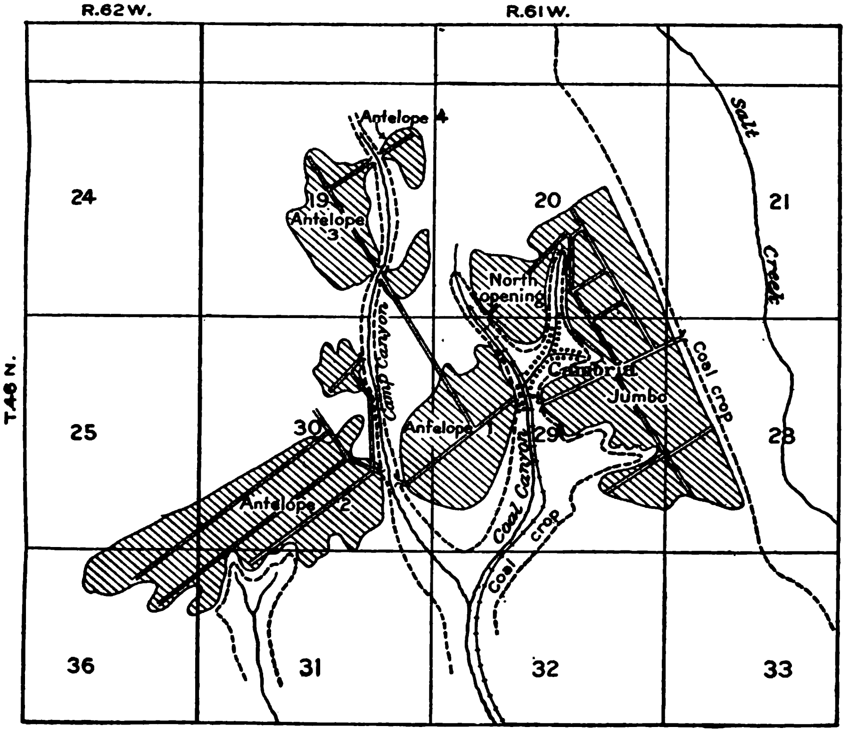


FIGURE 6.—Extent of mine workings at Cambria, Wyo.

On account of their separation by these canyons the different mining operations are considered as separate mines, as shown on the map (fig. 6).

The Jumbo mine is situated on the east of Coal Canyon and extends through to the rim wall or escarpment on Salt Creek, a distance of 3,400 feet. The north and south length of the mine is about 8,000 feet.

North Opening is the name of the mine lying between the forks of Coal Canyon. Its main entry has been driven east to connect with the north workings of the Jumbo mine.

Antelope mine No. 1 is between Camp and Coal canyons. Through it passes a tunnel 3,200 feet from portal to portal, by which Antelope No. 2 on the west side of Camp Canyon is reached. Haulage between the two mines is maintained over a 400-foot trestle about 85 feet high, which spans Camp Canyon. (See Pl. III, *B*, p. 18.)

Antelope mine No. 2, which lies entirely west of Camp Canyon, has a length of about 6,800 feet and an average width of 2,000 feet.

The main entry to Antelope mine No. 3 is about three-fourths of a mile northwest of Cambria on the west side of Camp Canyon, well toward its head. It is reached by a long tunnel driven from the main entry in Antelope No. 1. Camp Canyon is crossed by a trestle about a mile above that connecting Antelope Nos. 1 and 2.

Antelope mine No. 4 is on the east side of the head of Camp Canyon and is the latest development. It is reported that the recent work in this mine has opened up a fine body of coal, and it is presumed that for the present work will be pushed in its direction.

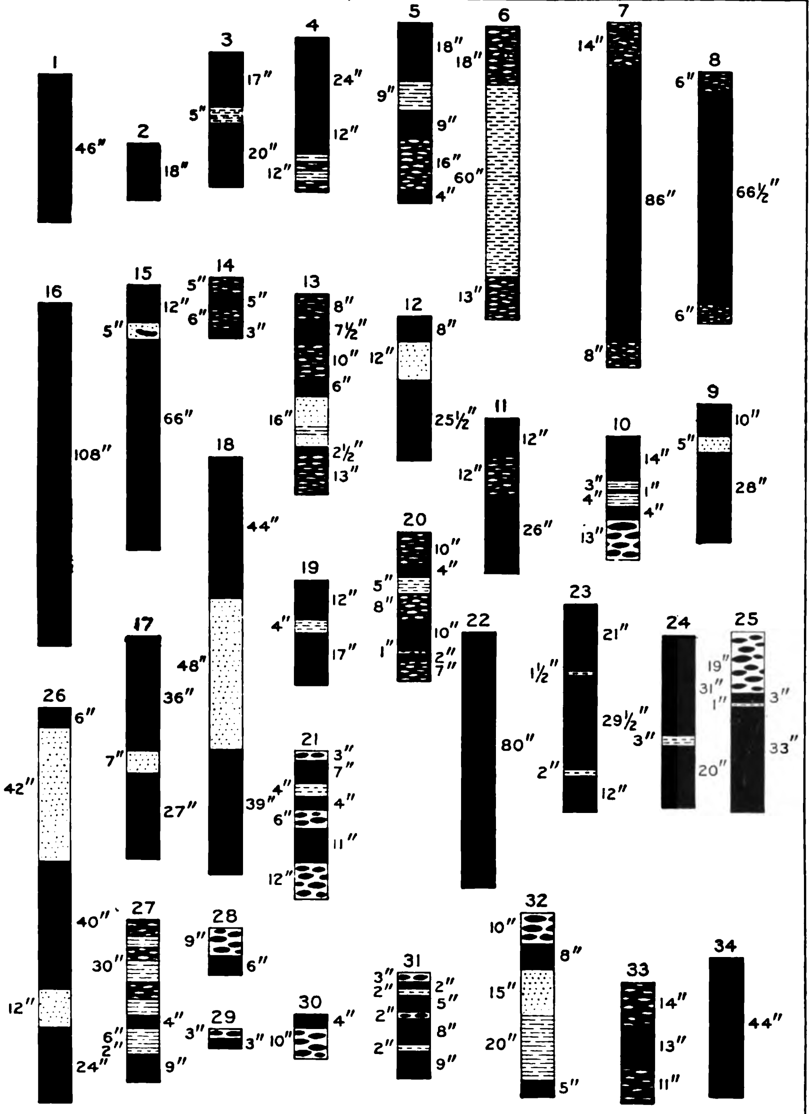
All haulage from Antelope mines Nos. 2, 3, and 4 is through Antelope No. 1, and delivery is made at a single tipple on the east side of Coal Canyon, over about 50 miles of 42-inch gauge track. Rails weighing 25 pounds to the yard are used in the main entries and 16-pound rails in the side entries and rooms.

The room-and-pillar method of mining is used, except in a few districts where the thinness of the bed makes the long-wall system more economical. Mining is done by subdistricts composed of a minimum of 10 rooms. After all the rooms in a subdistrict are worked out the inside pillars are drawn, leaving the chain pillars to protect entries. Early in the development of these mines the rooms were opened 40 feet wide, but this was found to be too great a width for safe working and 24 feet was adopted as giving the best results. The single-entry system is never used in these mines.

The coal is all cut by machine, being too hard for hand mining. Nearly all of the underground work is done on the contract system, the men being paid a certain price per car, varied to suit the conditions of the work at each place.

CHARACTER OF THE BED.

The coal is hard bituminous, with bands of dull coal, locally called splint and cannel. In places the bed is solid coal, in others it is separated into two or three benches by clay or sandstone partings. (See Pl. IV.) The following sections show the thickness of the coal bed in five districts of the mines at Cambria as reported to the company by the secretary, L. T. Wolle, in 1908, and by E. H. Lawall, M. E., of



EXPLANATION

■ Coal

■ Impure or bony coal

▨ Bone

▤ Clay

▤ Shale

⠿ Sandstone

Numbers on right of sections give thickness of coal

Numbers on left of sections give thickness of waste

Vertical scale 1 inch = 5 feet

LIST OF MINES AND PROSPECTS

1-2.	ALADDIN	7-9.	HOLWELL	17-18.	CAMP CANYON	27.	GRANT CANYON
3.	BOLTON	10-11.	SPENCER	19-22.	ANTELOPE 2 & 3	28-29.	NEWCASTLE
4.	ROGERS	12-13.	E. PLUM CR.	23.	JUMBO	30.	ROBBERS ROOST
5.	MILLER	14.	SALT SPRING	24-25.	ANTELOPE 1	31.	COAL CANYON
6.	MASON CR.	15-16.	ANTELOPE 3 & 4	26.	MT. ZION	32-34.	CHEYENNE R.

SECTIONS OF COAL BEDS NEAR BLACK HILLS.

Wilkes-Barre, Pa., in 1902. Wolle's figures were obtained by computation from area worked out and actual tonnage yielded and do not include splint that was "gobbed." Lawall's figures are averages of the thickness of the bed as actually measured in the mine. Averaging all the measurements proportionally to the area of the respective mines gives an average thickness of about 5 feet for the bed as exposed in the underground workings.

Average thickness of coal bed in Cambria mines.

Mine.	Wolle.		Lawall.	
	Ft.	*in.*	*Ft.*	*in.*
Jumbo	5	8	5	9[illegible]
North opening	4	8	4	8[illegible]
Antelope No. 1	4	2	4	3[illegible]
Antelope No. 2	4	8	4	10[illegible]
Antelope No. 3	4	2		

In some places in Antelope No. 3 and No. 4 the thickness of the bed is considerably above the average, as shown by the two following sections measured by W. E. Mouck, superintendent of the mines:

Section of coal bed in fifth west entry, Antelope mine No. 3.

	Ft.	in.
Coal, good (bituminous)	1	
Coal and sandstone		5
Coal, cannel	2	8
Coal, good		7
Coal, splint, good		6
Coal, good	1	3
Coal, splint, good		6
	6	11

It is understood that in 1909 the company opened up in Antelope mine No. 4 an excellent body of coal, which is in some places 10 feet thick. (See Pl. IV.) The section below gives the details of the bed as it commonly occurs in this mine:

Section of coal bed in first east entry off main south entry, Antelope mine No. 4.

	Ft.	in.
Coal, good (bituminous)	1	6
Coal, splint, good		2
Coal, good		4
Coal, splint, coarse		1
Coal, good		6
Coal, medium		2
Coal, good		8
Coal, medium		1
Coal, good	3	
Coal, splint, good	2	
Coal, good		6
	9	

The thickness of the bed varies with the position of the floor, which is slightly wavy, and also with the thickness of the partings. This is shown at the head of Camp Canyon in entries on the east and west sides of the stream.

Sections of coal bed in Camp Canyon.

Section.	East.		West.	
	Ft.	in.	Ft.	in.
Coal	3		3	8
Sandstone		7	4	
Coal	2	3	3	3
	5	10	10	11

The east section was measured about 180 feet from the entry, and the west section 200 feet from the entry. In driving the main entries in Antelope mine No. 3 to this entry from the west side of the canyon it was found that the 4-foot sandstone parting is only of very small lateral extent.

In places in the Cambria mines the Lakota coal is so thin and bony that its mining is not at present profitable. Two sections measured 6 feet apart in room 104 of No. 6 west in Antelope mine No. 2 are given below:

Sections of coal bed in Antelope mine No. 2.

	Ft.	in.
Sandstone, white, soft, roof.		
Coal, bituminous, bright, solid		12
Clay, drab, soft		4
Coal, bony, very hard		5
Coal, bituminous, bright		8
Coal, bony, hard		2
Coal, bright		1–2
Sandstone floor.		
	2	8

	Ft.	in.
Sandstone roof.		
Sandstone, brown, carbonaceous.		½–3
Coal and bone		10
Coal, bituminous, bright		4
Clay, drab, hard		5
Bone		8
Coal, bituminous, bright		10
Clay		1
Coal, bituminous, bright		2
Bone and coal		7
Sandstone floor.		
	4	2

About 300 feet due west from room 104 the following section was measured:

Section of coal bed at roll in Antelope mine No. 2.

	Ft.	in.
Sandstone roof.		
Bone with bright coal streaks		3
Clay in lenses		0-2
Coal, mostly bright, with bony streaks		7
Clay, hard		4
Coal, bright		4
Bone		6
Coal, bright		11
Bone, with streaks of bright coal		12
	4	1

This section is on a roll which has an east-west strike and dips 50° to 60° S. Although the bed is thin here, it is possible that the roll has no great width and more workable coal lies beyond it. The bed at this point is mined by the long-wall method.

The thickness and character of the coal bed in the Cambria mines is further illustrated by the following four sections measured by Frank W. DeWolf in different parts of the mines.[1] Section A was measured in room 6 off the third northwest entry in Antelope No. 3 mine; section B, in room 9 off the eighth northwest entry in Jumbo mine; section C, in room 7 northwest in Antelope No. 1 mine; and section D, in room 14 in Antelope No. 1 mine.

Sections of coal bed in the Cambria mine, Cambria, Wyo.

Section A.

Sandstone.	Ft.	In.
Coal	2	
Coal, splint		7
Coal		6
Coal, splint		2
Coal	1	10
Coal, splint		10
Coal		6
Coal, splint		3
	6	8

Section B.

Shale, black.	Ft.	In.
Coal (cannel?)		2
Coal		2
Coal, splint		7
Coal		10
Clay		1½
Coal		3
Coal, splint		5
Coal	1	2½
Coal, splint		3
Coal		4
Clay		2
Coal	1	
	5	6

Section C.

Sandstone.	Ft.	In.
Shale, black		4
Clay	1	5
Bone		3
Clay	1	
Coal	1	5
Sulphur		½
Coal	1	2¼
Clay		3
Coal	1	8½
Fireclay.		
Total coal	4	7

Section D.

Sandstone.	Ft.	In.
Shale		3
Bone	1	7
Coal, splint		2¾
Clay		1
Coal	2	9
Fireclay.		
Total coal	3	¾

Analyses Nos. 1376, 1377, and 1571 (p. 53) represent samples taken during the process of testing this coal at St. Louis during the Louisiana Purchase Exposition. Nos. 1376 and 1377 represent the coal at the places where sections A, B, and C were measured, and No. 1571 represents a carload shipped to the testing plant. Analyses 6790, 6792, and 6793 were taken by the writer and represent different grades of coal from these mines.

---

[1] Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition: Prof. Paper U. S. Geol. Survey No. 48, pt. 1, pp. 139-140.

Mining has been discontinued where the bed is less than 3 feet thick, but drilling in advance of the breast has proved that under a considerable area as yet undeveloped the bed is from 4 to 8 feet thick.

VILLAGE AND MINE EQUIPMENT.[1]

By C. T. LUPTON.

POPULATION AND BUILDINGS.

Cambria is a small village located in the bottom of the canyon of Little Oil Creek on a branch known as Coal Canyon. It is distinctly a mining camp, having been built up and developed by the Cambria Fuel Co. around the coal-mining plant. The population naturally consists entirely of officers and miners employed in coal mining. Between 400 and 450 miners, mostly foreigners, are constantly engaged at the mine and with their families make a population of about 1,400 persons. The Cambria Fuel Co. owns a large area of land in the vicinity and has complete control of the village and its surroundings. Besides its two-story office building, located at the forks of the canyon in the middle of the village, and the necessary mine houses, the company has constructed about 150 modest but substantial frame houses for the use of the miners. Most of these houses, together with two or three churches, are located in the bottom of the canyon. (See Pl. V, *B*.)

As the population increased, a little settlement known as Antelope City was built, in 1892, on the plateau above the tipple at Cambria. This consists of 31 small frame houses and a large two-story schoolhouse. The school children, by this arrangement, spend a greater part of the school days away from the noise and traffic of the main village and in the purer air of the plateau.

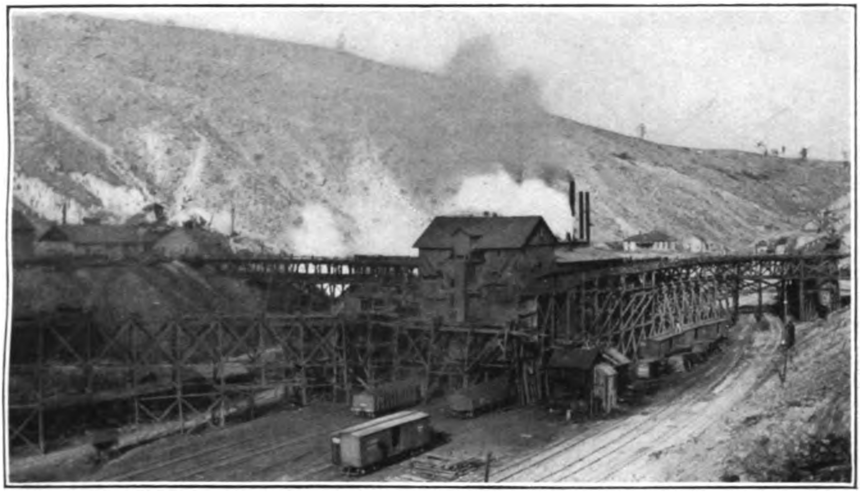
The miners' houses are supplied with running water from a gravity system built by the company and are lighted with electricity. Many of them also are supplied with steam heat.

The company owns and operates the only store in the village, and, through it, supplies all the demands of miners and ranchmen in a radius of several miles for merchandise and provisions. By means of its large land holdings the company is able to prohibit the sale of liquor at the mines, the nearest saloon being at Newcastle, about 8 miles distant. Because of this arrangement, and also on account of the fair treatment accorded the miners, the company has had no trouble with strikes or other disturbances so common in mining towns.

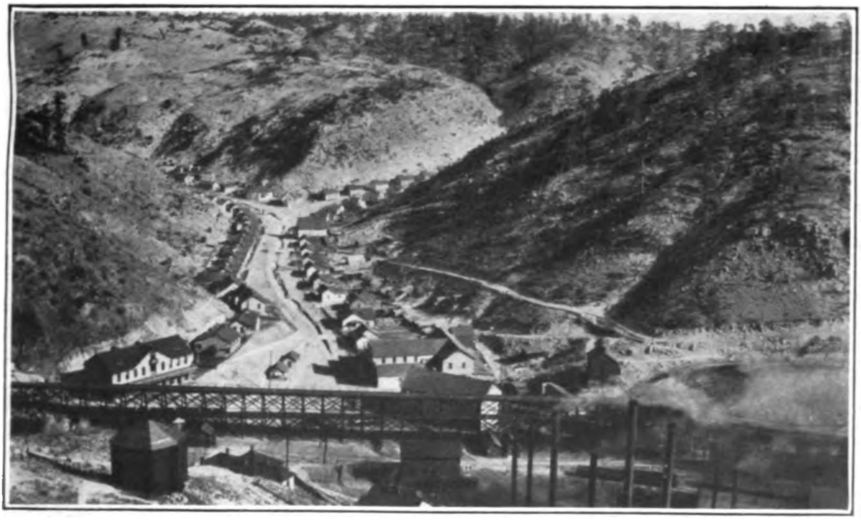
The mining company operates a large hotel for the benefit of those who prefer it to a separate residence or boarding house. It also

---

[1] Part of the information here presented is derived from the paper by Chenhall, listed on page 6.



A. CAMBRIA FUEL CO.'S TIPPLE AT CAMBRIA, WYO.



B. VIEW OF CAMBRIA, WYO.

maintains a small but well-equipped hospital (the only one in Weston County) in charge of a physician and a trained nurse.

For the daily use and convenience of the miners the company also maintains a bathhouse fitted with a large number of individual washbowls, with hot and cold water, shower and tub baths, and lockers. This feature of the mining camp is greatly appreciated by the men and may in part account for the pleasant relations between employers and employees.

RAILROAD FACILITIES.

Cambria is the northern terminus of a branch of what was formerly known as the Burlington & Missouri River Railroad but is now the Chicago, Burlington & Quincy Railroad. The branch is 7.8 miles long and connects Cambria with the main line at Newcastle. It is a single-track railroad built along the valley bottom, with a necessarily heavy grade, which favors the loaded coal cars. All necessary yardage has been constructed at Cambria, so that supplies are unloaded directly at the warehouse, and the loading tracks pass beneath the tipple. There is sufficient room above the tipple for 50 or 60 cars.

WATER SUPPLY.

Cambria derives an abundant supply of excellent water from Sweetwater Mountain, Mount Pisgah, and a deep well.

Sweetwater Mountain, which lies 6 miles north of Cambria, is so named because its numerous springs are not alkaline. Water from several springs on the east side of the mountain is piped to a main line which carries it around the face of the escarpment on the west of Salt Creek to the Jumbo Tunnel at its eastern end, through the Jumbo mine, and into a large covered reservoir below the mouth of Grant Canyon. This lower reservoir constitutes the supply for the city of Newcastle. On emergency, the water can be turned into an upper reservoir and used for the boilers and the compressed-air cooler.

Mount Pisgah is 4 miles northeast of Cambria, on the east side of the deep valley of Salt Creek. Curious as it may seem, there are a number of springs at the base of the Lakota sandstone close to the top of the mountain. The water from some of these springs is piped by gravity across the valley of Salt Creek and over the ridge at the road gap to Cambria, where it furnishes sufficient pressure for excellent fire protection. Water from this system is stored in an open cement-lined reservoir at the upper end of the village. The supply from this source is estimated from 30,000 to 40,000 gallons daily.

A well just above the tipple at Cambria was drilled to a depth of 2,345 feet and obtained a strong flow of water about 2,115 feet below the surface, in the Pahasapa limestone. This water, which is of excellent quality, rises under artesian head to within 500 feet of the surface and is reported to yield at least 200 gallons a minute. In fact, it is said that in a test which lasted more than two hours the well was pumped at the rate of 225 gallons a minute without lowering the level of the water.

A unique method of pumping, devised by the superintendent, W. E. Mouck, is used at this well. An 8-inch casing to 900 feet cuts off alkaline water. Inside this is a 5½-inch (outside diameter) pipe extending down about 2,000 feet. This pipe is carried above the surface to a tank situated on the hillside 160 feet above the well mouth. A pipe 1 inch in diameter for about 1,200 feet and ¾ inch for 480 feet more, with end turned up and opening reduced to ⅜ inch, carries compressed air about 1,700 feet below the mouth of the well, or about 1,200 feet below the surface of the water. This pipe enters the inside pipe at the well mouth with a tight joint. When it is desired to fill the tank, compressed air is discharged through this small pipe with a pressure of from 700 to 800 pounds to the square inch. The result is that the water is discharged into the tank in a 5-inch column with considerable violence. The pressure of the water when the tank is full is between 63 and 73 pounds per square inch on the gages in the compressor room. This pressure is sufficient to furnish excellent fire protection for the mine buildings. Antelope City, which is situated on the plateau above, is supplied with running water from a tank, which is filled by steam pump from the lower tank on the hillside.

The village is equipped with two hose carts which carry a large reel of 2½-inch hose, and, as described above, the gravity pressure in the pipe lines is sufficient to throw a strong stream. Besides the water system, the company buildings and the mines are supplied with several dozen portable chemical fire extinguishers.

MECHANICAL EQUIPMENT.

Workshops.—At the lower end of the village and along the west side of the railroad the company maintains substantial frame buildings for the power plant and for workshops. The latter are equipped not only for making all repairs needed at the mines, but also for constructing any special machinery that may be needed. Although the available land adjacent to the mine entries is small, the buildings are all located conveniently to the tipple, the mine entries, and the railroad track.

Mining machinery.—The power plant at the Cambria mines included in 1908 a battery of nine boilers. This battery consists of three Heine boilers of 300 to 350, 375 to 425, and 425 to 525 horsepower capacity; three Drake, Wilson & Williams boilers and two

Kewanee boilers of 150 horsepower each; and one marine boiler of 125 horsepower capacity. This gives a total of 1,975 to 2,175 horsepower.

The boilers are fed with fine slack and unmerchantable coal derived from the screens. They are fired by three shifts of six firemen each. Automatic stokers were used for a time but have been withdrawn because they were not so successful as hand firing.

As the coal in the Cambria mines is too hard to cut by hand all mining is done by power machines. The system used is compressed air, and the mine plant is equipped with six compressors of the following make: One Ingersoll, 70 to 85 pounds pressure, made by the Ingersoll-Rand Co., New York; three "low pressure," 70 to 100 pounds, made at South Norwalk, Conn.; and two "high pressure," 750 to 1,000 pounds, made at South Norwalk, Conn. These compressors, which distribute compressed air throughout the mines by the usual piping system, operate coal cutters and drilling machines and also furnish power for air motors used in collecting cars from the rooms and making up trips. Nine Porter air motors are in use, seven of them in Antelope mine No. 3 and two in Antelope mine No. 2, as follows: Five 7-ton motors, one 15-ton, and three 5-ton.

The company has seventeen H4 and seven G2 Ingersoll-Rand punchers in use in the mines, besides two Harrison punchers, twelve G2 punchers, and three H4 punchers, that are not in use. The H4 has proved to be the better machine for this hard coal.

The coal is hauled from both the Antelope and the Jumbo mines by the tail-rope system. An engine located at the mouth of Antelope mine No. 1, which is close beside the tipple, has 500-horsepower capacity and operates a haulage system 1½ miles long. The engine, which is of the first motion clutch type, was built at the Ottumwa Iron Works, Iowa; the cylinders are 24 inches by 34 inches and the drum 5 feet in diameter and 5 feet wide between the flanges, which are 6½ feet in diameter. The capacity of the drums is 2½ miles of ⅞-inch wire rope. The trips from this mine consist of 39 cars, each with a capacity of about 3,600 pounds of coal.

At the Jumbo mine a haulage engine is located about 300 feet in from the entrance. It was built by the Nelsonville Foundry & Machine Co., of Nelsonville, Ohio, and may be described as a double-drum engine, geared five to one, with two cylinders 16 inches by 24 inches, the drums being 6 feet in diameter and 2 feet 6 inches wide between the flanges, the latter being 12 inches deep, with a capacity for holding about 1½ miles of 1-inch wire rope on each drum. The average trip consists of 20 trip cars, each weighing about 1,800 pounds and containing about 4,000 pounds of coal. The trips are hauled by a steel-wire rope, 1 inch in diameter, of six 9-wire strands. A rope of this diameter with nine wires to the strand and the Lang lay has been found to give longer service than one with seven wires and the regular lay. The main line takes the trip in to a distance of 3,000 feet, the rope passing around a 6-foot bull wheel placed under the track. About 1,500 feet beyond this a second engine, located at the top of the second grade in the mine, takes the trip up the second grade, from which point the cars are distributed through the mine by horses and mules. The second system has about one-half mile of cable. The trips coming out from the mine are delivered by the rope at the beginning of the trestle and let down by gravity to the tipple. After being dumped, the cars run by gravity to the foot of the incline, from which point they are taken by the rope.

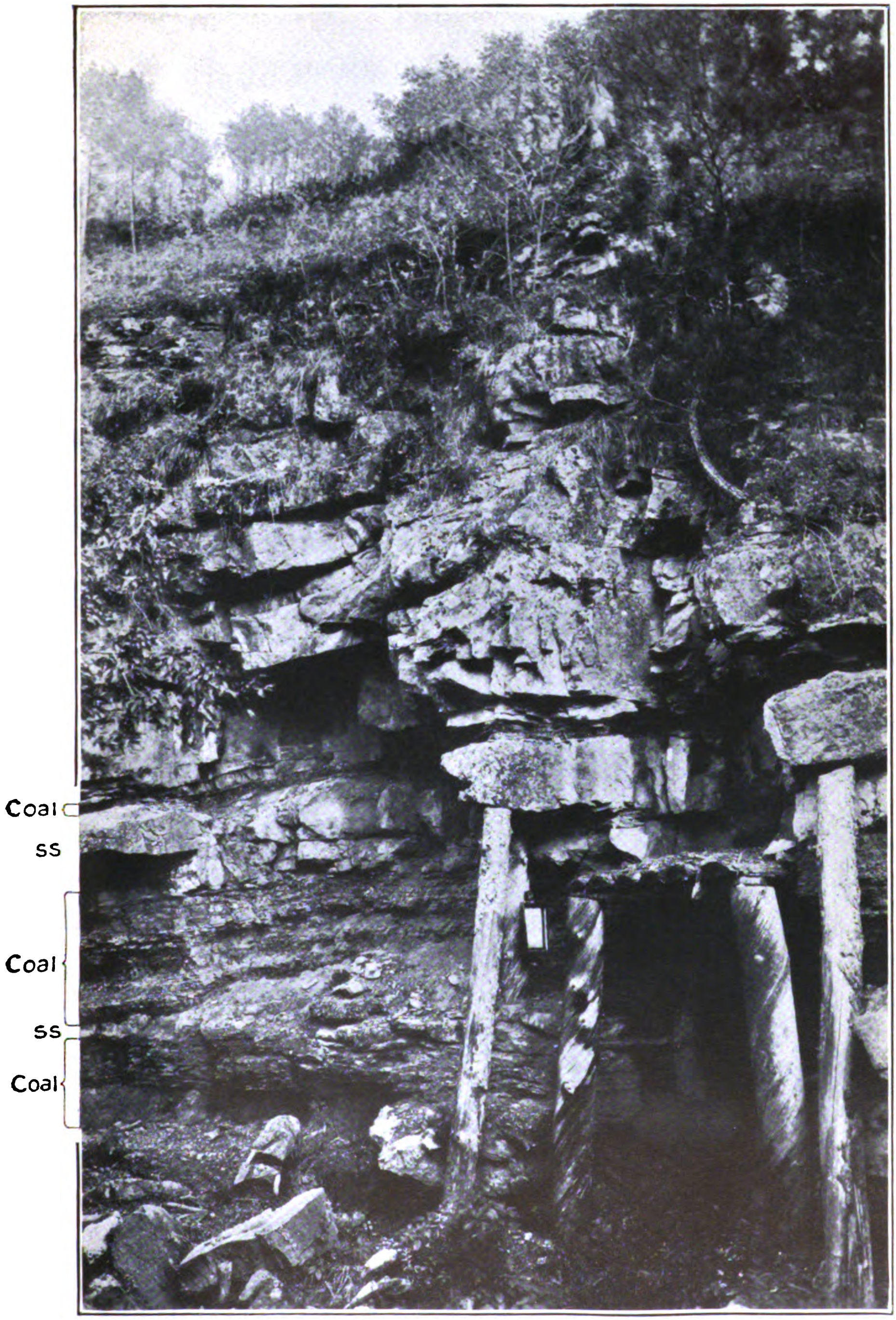
The village of Cambria is lighted by electricity, and the mines have an electric signal system. The power is produced by 3 dynamos, as follows: One Edison 60 kilowatts of 125 volts; one Standard dynamo of 110 volts, which furnishes the power for a telephone and signal system and electric lights in the shops and houses; and 1 Milwaukee of 12½ kilowatts, 42 amperes, and 300 volts, which runs the telpher.

Ventilation.—The mines are free from gas or fire damp, and the need of a system of ventilation is mainly to remove the vitiated air. This is done by exhaust fans located at the main entrances. Fans 20 feet in diameter equip each of the mines except the Antelope No. 4, which has an 18-foot fan, and the Jumbo mine, which has a 25-foot fan.

Tipple.—The coal from all of the mines is brought to a common tipple in Coal Canyon. (See Pl. V, *A*.) The mine cars are dumped by Mitchell tipples, and all of the coal is crushed and screened by plate and revolving screens. The slack, or that portion of the coal which goes through a $\frac{5}{16}$-inch mesh, is carried by belt conveyer to storage bins and sold to steam plants and used under the boilers at the power plant. All other coal, or 85 per cent of the output, is shipped and used almost exclusively by the Chicago, Burlington & Quincy Railroad on its locomotives. The coal is loaded into open railroad cars on three tracks and into box cars, with box-car loaders, on two others, there being five loading tracks in constant use. One of these loaders is of the Christy type and the other is a gravity loader used when there are doors or windows in the end of the car. Approximately one-half of all the coal shipped from Cambria is sent out in box cars.

OUTPUT.

The output of coal from the mines at Cambria began with 2,985 short tons in 1889 and increased to 542,649 tons in 1899. Since the latter date the production has gradually decreased to something over 300,000 tons in 1908. The total production of the mines up to December 31, 1908, amounted to over 7,500,000 tons.



OPENING ON COAL AT MOUNT ZION RANCH, NEAR CAMBRIA, WYO.

MOUNT ZION.

Southwest from Cambria the coal bed outcrops in the ravine at the Mount Zion ranch, in sec. 11, T. 45 N., R. 62 W. (See Pl. VI.)

Section of coal bed at Mount Zion ranch.

	Ft.	in.
Sandstone, white, massive	12	
Coal, bituminous		2-6
Sandstone, white, massive	3-4	
Coal, bituminous	3	4
Sandstone, gray, hard		6-20
Coal, bituminous, ashy	2	
Sandstone, gray, massive	50	

The top bench is bright coal that has a splintery fracture, breaking in long, thin chips. The middle bench is solid, clean, bright coal, which works with a smooth, vertical face, but varies in thickness on account of sandstone partings. At the base of the bottom bench, which is a somewhat flaky coal and is apparently high in ash, a peculiar band is composed of a mass of irregularly disposed carbonized fibers resembling pine needles.

The coal shown in the section given above is exposed in a 50-foot drift in the south wall of the ravine. A 30-foot drift in the opposite bank, driven on the middle bench, shows 40 to 42 inches of clean coal. South and west of this outcrop the coal bed is carried rapidly to a considerable depth by a sharp increase in the dip.

LITTLE OIL CREEK.

From the mouth of Camp Canyon to Newcastle very little coal has been found. In the first draw on the west below the mouth of Grant Canyon a 100-foot drift by the roadside shows a thin coal bed between a massive white sandstone roof and floor.

Section of coal bed below Grant Canyon.

	Ft.	in.
Shale, brown, with coal streaks		5
Coal and shale, drab and brown	2	6
Coal, bituminous		2-4
Shale, carbonaceous, and coal streaks		5-7
Clay and iron and iron nodules		2
Coal, bituminous		9
Sandstone floor.		

This bed has a total thickness of about 20 inches and is believed to be the one mined at Cambria. No other coal was seen along the road, although the rocks are fairly well exposed.

About 1 mile north of Newcastle, where the coal horizon is carried below water level, two measurements of the bed were obtained, showing 9 inches of bone on 6 of coal and 3 inches of bone on 3 of coal.

These sections and the fact that in the canyons on the east and west of this locality near Newcastle the coal horizon is represented by a small band of carbonaceous shale, indicate the nonworkable character of the Lakota coal south of Cambria.

ROBBERSROOST CANYON.

At the head of Robbersroost Canyon a prospect, said to be in the NW. ¼ NE. ¼ sec. 9, T. 45 N., R. 61 W., is driven 40 feet west, just below the edge of the plateau. A section of the coal bed shows 4 inches of bituminous, flaky coal on 10 inches of ashy coal or bone lying between massive sandstones. The writer is informed by others that the bed here consists of 18 inches of splinty coal and that ashes in the bed show that part of the coal has burned. His own observations are as given above. In the stream 60 to 70 feet below and at the base of a massive sandstone ledge there is about a foot of brown carbonaceous shale. Both of these exposures are about 50 yards below a rock-rimmed pool 20 feet in diameter near the head of the canyon. The writer is uncertain as to which of these beds is the one mined at Cambria, but in either case it is evident that the Lakota sandstone does not carry coal of workable thickness in this part of the township.

SALT CREEK.

On account of the heavy talus from the overlying sandstones, the coal horizon along the west side of Salt Creek can be seen only rarely, and measurements are difficult to obtain, although the outcrop is long. The southernmost exposure of the Lakota coal bed examined in this district is 3 miles southeast of Newcastle at the first crossing on Salt Creek. A drift in the east bank is caved, but the following section was measured at the entry:

Section of coal bed on Salt Creek.

	Ft.	in.
Sandstone, white, massive	10	
Sand, with carbonaceous streaks		6
Sandstone, white, massive	2	
Clay, drab and gray	3	
Shale, brown, sandy, carbonaceous		2–6
Shale, brown, with coal streaks	4	
Coal, bituminous, shaly, ashy		6
Shale, brown, weathers gray		4
Shale, brown, carbonaceous		4
Clay, drab	6	
Shale, carbonaceous, fissile	2	

This drift must have been driven with the idea that coal of workable thickness and quality would be found under the hill and the project abandoned when the hope was not realized.

EDGEMONT.

About 8 miles north of Edgemont in Coal Canyon, in or near sec. 22, T. 7 S., R. 2 E., there are several prospects on the coal in the Lakota sandstone. (See fig. 7.) The largest of these is a drift about 75 feet long driven in the east bank of the canyon well toward its head. A second entry joins the first about 60 feet from the mouth. At this junction a small fault, probably due to landslipping, practically cuts out the coal. At the face of the prospect the bed shows signs of movement, but the coal is fresh and hard. The section under the massive white sandstone roof follows:

Section of coal bed in Coal Canyon.

	Inches.
Bone with coaly streaks	3
Coal, bituminous	2
Clay, black	2
Coal, bituminous	5
Bone	2
Coal, bituminous	8
Clay, carbonaceous	2
Coal, very hard, splinty	9
	33

This prospect, according to Harry Snyder, who kindly guided the writer to it, was opened by Fred Anthony about 1893. The poor character of the bed and the extreme difficulty of gaining access to the bottom of the canyon at this point with a wagon explain why the prospect has not been developed further.

On the west side of the canyon a few rods below Anthony's prospect a crooked drift has been driven about 300 feet in massive white sandstone, following a thin carbonaceous band. At some points the bed of carbonaceous shale, bone, and coal is nearly a foot thick, but the bone or shale predominates. Nowhere does the bed carry more than 5 or 6 inches of bituminous coal. Between these two drifts two prospects show from 1 to 2 feet of carbonaceous shale with a band of coal up to 6 inches thick. A few rods farther down the canyon two or three prospects appear on the same coal horizon; one shows 3 feet of brown shale overlain by about 8 inches of coaly shale; another shows only brown shale.

A prospect opened in the head of Bennett Canyon in the winter of 1907–8 is reported to show about the same small amount of coal as in Coal Canyon.

Three miles east of Edgemont, on the south side of Cheyenne River, under a ledge of massive buff Dakota sandstone, a large prospect drift is caved full, so that access can not be had. Black shale and a small amount of bony coal were found on the dump. An outcrop near by shows that the bed consists of a few inches of black carbonaceous shale resting on brown woody shale.

Two miles farther east in the north part of sec. 11, T. 9. S., R. 3 E., and about 150 feet above Cheyenne River two drifts have been driven 10 yards apart on a coal bed in the Lakota sandstone. There is at least 20 feet of massive sandstone below the coal and a few feet of shaly sandstone above. The drifts are caved and nothing was learned about the thickness of the bed. Probably it thinned or pinched out, for after a road was graded and a stone-loading platform built the project was abandoned. Most of the coal found on the dump is bony or composed of a mass of carbonized fibers. One lump of bright bituminous coal 5 inches thick was seen.

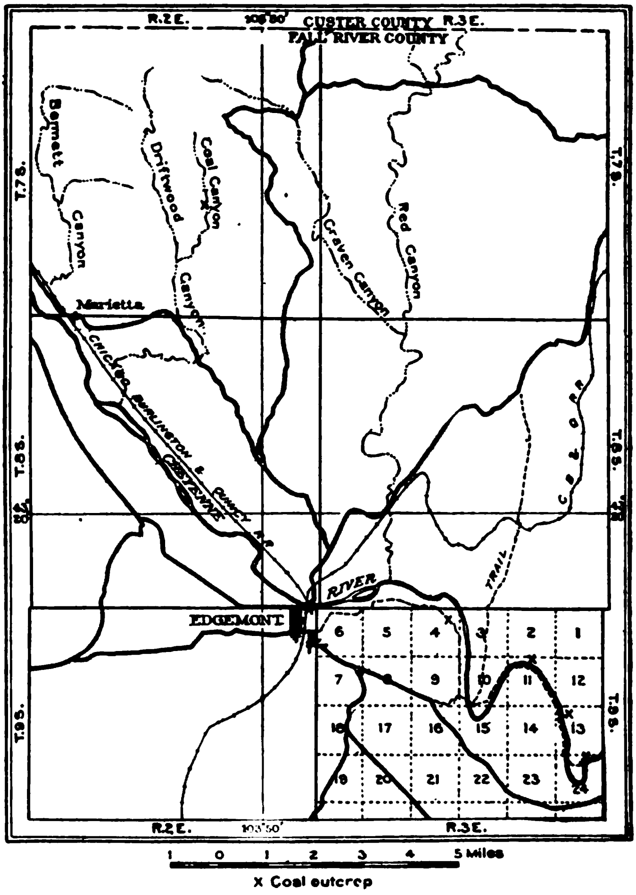


FIGURE 7.—Map showing location of coal near Edgemont, S. Dak.

On the north side of Cheyenne River, in the N. ½ sec. 13, T. 9 S., R. 3 E., two measurements of the Lakota coal were obtained about

60 feet above the river. The first of these is a natural exposure and the second is at the entrance of a small prospect drift about 50 feet away, which is nearly closed by caving.

Sections of coal bed 6 miles east of Edgemont.

	Ft.	in.
Sandstone, gray, massive	20	
Shale, carbonaceous		10
Sandstone, gray, massive	5	
Cannel or shaly bone		10
Coal, bituminous		8
Sandstone, gray, massive	1	3
Shale, brown	1	8
Coal, bituminous		5
Shale, brown, sandy	1	2
Sandstone, gray, massive	25	

	Ft.	in.
Sandstone, gray, massive	20	
Shale, carbonaceous		2
Sandstone, carbonaceous		2
Bone and bony coal	1	2
Coal, bituminous	1	1
Coal, bony		11
Sandstone, gray, massive.		

Neither the quantity nor quality of the coal in the prospect warrants further development.

The thickest bed of coal known in the vicinity of Edgemont is in the southernmost bend of Cheyenne River 7 miles east of town. Here in the NW. ¼ NE. ¼ sec. 24, T. 9 N., R. 3 E., in the sandstone bluff of the north river bank and but a few feet above water, two drifts have been driven about 30 feet apart. The main one is 10 feet wide and runs back under the massive sandstone roof at least 100 feet. The bed exposed in this drift is from 44 to 54 inches of splint coal, like the splint in the Cambria mines and like the lower part of the bed at Aladdin. The middle of the bed shows a few inches of bright bituminous coal. The second drift shows 44 inches of splint coal, with two or three 1-inch seams of bright bituminous coal near the top. Within about 150 feet to the east the coal pinches down to a streak not over 2 inches thick, and in the opposite direction in about the same distance the coal disappears, and the position of the bed is marked by a few inches of coaly shale. Figure 8 shows the occurrence of this small pocket of coal as exposed in the river bluff.

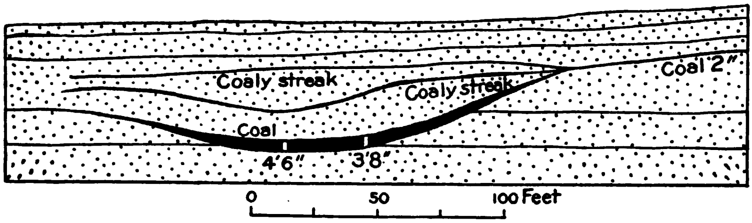


FIGURE 8.—Diagrammatic section of coal bed exposed in bank of Cheyenne River, east of Edgemont, S. Dak.

EAST SIDE OF BLACK HILLS.

The writer has no personal knowledge of any coal on the east side of the Black Hills. The only reference found is the following brief statement by J. E. Todd:[1]

> At probably the same horizon (Lakota), beds of coal a few inches thick have been discovered near Rapid City, Whitewood, and southwest of Minnekahta. The only chance of finding workable beds in such localities is the possible occurrence of "pockets" of very limited extent. Such occurrence is extremely improbable.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

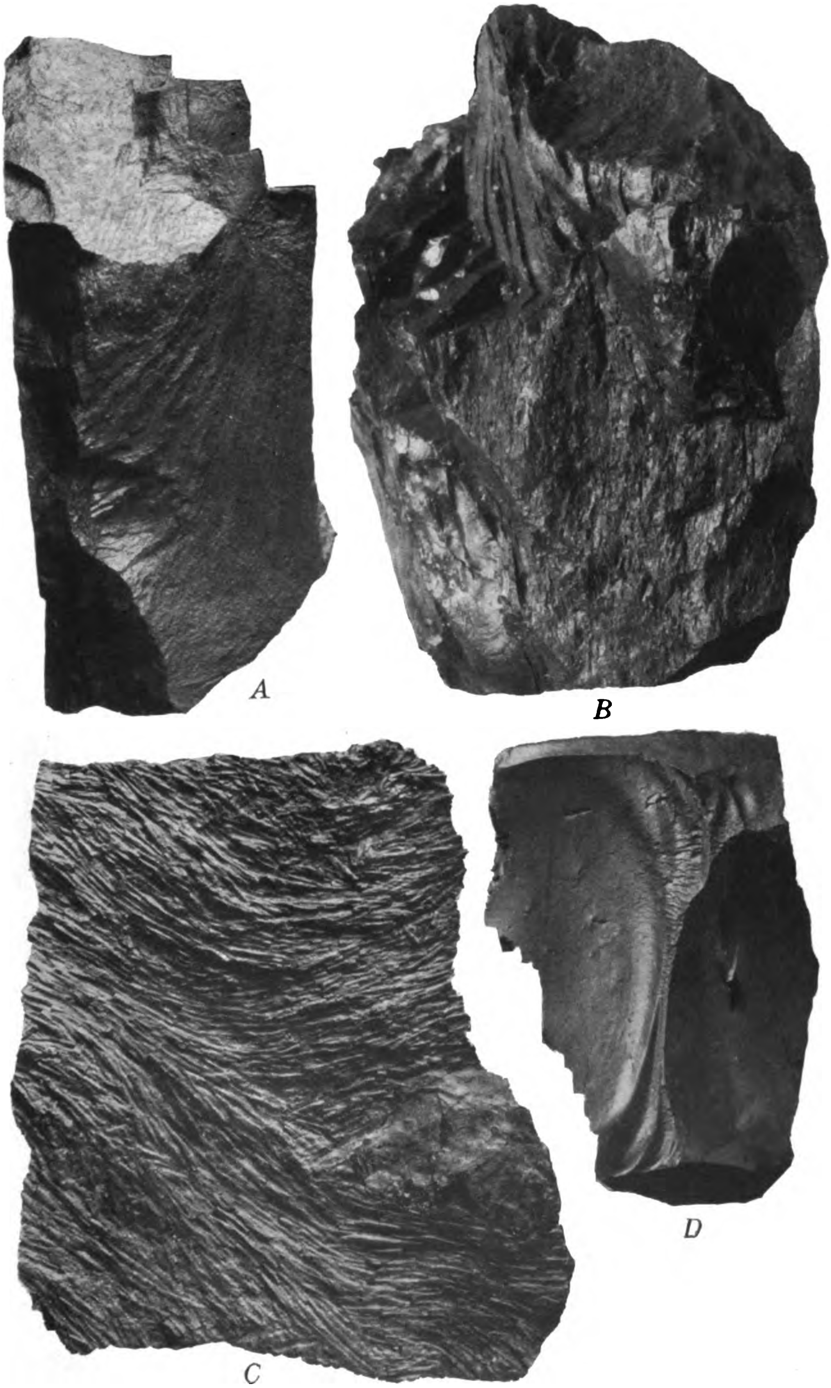
The United States Geological Survey recognizes six grades of coal—anthracite, semianthracite, semibituminous, bituminous, subbituminous, lignite. Chemical analysis alone is not sufficient to separate all these grades because every variation in composition occurs, from lignite, which is high in volatile matter, to anthracite, which is high in fixed carbon, and no sharp distinction between the different grades is possible. Physical character, as well as chemical, must be used to distinguish the grades. The effects of weathering furnish an important criterion for separating bituminous coal from subbituminous and lignite. Bituminous coal has a well-developed joint system, which is recognizable even on small fragments, and it does not disintegrate readily. Subbituminous coal and lignite, however, on exposure to weather rapidly lose moisture, crack or check with irregular fracture, and quickly fall to pieces. High-grade lignite and low-grade bituminous coal range between 9,500 to 12,000 British thermal units in unweathered air-dried samples.

Practically all of the coal in the Black Hills has more or less pronounced prismatic cleavage, has a calorific value on air-dried sample above 10,000 British thermal units, does not check on exposure to the weather, and so must be classed as bituminous. The calorific value of these coals, however, is low on account of the high percentage of ash which some of them contain. (Calculated as pure coal free of ash and moisture, the British thermal units in all are above 13,000.) The coal from certain benches at Cambria and at Holwell's shows more than 12,000 British thermal units in air-dried samples, and is therefore high-grade bituminous.

In spite of the fact that coal in the Black Hills region occurs only in isolated patches of small extent, all beds, wherever found, have practically the same physical characteristics. Where the coal bed has a thickness of more than 2 feet it is usually divisible into benches of different grades, including bituminous, cannel, splint, and "pine-

---

[1] Todd, J. E., Mineral resources of South Dakota; Bull. South Dakota Geol. Survey No. 3, 1902, p. 111.



VIEWS SHOWING PHYSICAL CHARACTERS OF DIFFERENT COALS.

A, Splint; *B*, bituminous; *C*, "pine needle;" *D*, cannel.

needle" coal. Where thin the bed may be any one of these, and were thickest may contain all of them. (See Pl. VII.)

Bituminous coal is characterized by well-developed prismatic cleavage, by banded structure, and by an ability to withstand weathering. The banded structure is made by layers which are generally much less than an inch thick and which commonly measure from one-eighth inch down to mere films of alternating dull and bright glistening coal. Bituminous coal has a velvety luster and pitch-black color. It is not so brilliant nor so hard as anthracite.

Cannel is a lusterless, compact, even-textured coal, which has conchoidal fracture, breaks in blocks, does not disintegrate readily on exposure, ignites quickly, and burns without melting. Its color is velvety to dull black. It does not smut the hands. Cannel probably is formed from microscopic structureless algæ, and owes its difference from ordinary bituminous coal to its different origin.

Splint is used in this report to describe coal that is very hard, has dull luster, ignites with difficulty because of its impurity, and makes a large amount of ash. It resembles bony coal in appearance, but differs from bone in that it will burn. It may be homogeneous or contain laminæ of bright bituminous coal. Splint is inclined to break in long thin slabs. It is supposed to be composed of finely comminuted decomposed vegetable matter containing a considerable percentage of silt.

"Pine-needle" coal, which is found at most of the principal openings, forms no great part of the bed, but is worthy of mention because of its peculiarity. It consists of a mass of carbonized fibers resembling pine needles embedded in bony coal and containing more or less pyrite. The fibers are commonly oval and rarely round in cross section, from 1 to 3 or 4 inches long, and very elastic. They weather brown on the surface but are brilliant jet black within. They ignite readily with a match and burn freely with a thick, black smoke. These fibers occur as a thin bed 1 to 2 inches thick or may be scattered more or less abundantly in splint coal. The extreme variety of this coal is composed almost entirely of fibers and when deeply weathered resembles loose peat.

The name "pine needle" has been used before and, as it is fairly descriptive, will be retained here. The coal, however, is probably not derived from pine needles, as these commonly have one flat side or are semicircular in cross section, whereas these fibers have round or oval cross section. Furthermore, in the process of alteration from vegetable matter to coal considerable reduction in volume takes place, and as the fibers are the size of pine needles they must originally have been much larger than any known leaves of the

Pinus family. This coal has been given considerable attention by Dr. Thiessen, of the National Museum, who has been unable to find any anatomical structure indicating that the vermicular bodies are either stem, leaf, or root. On the contrary, he reports that they appear to consist of solid resin, which suggests that they may have been the filling of large vessels in some type of stem.

COKING QUALITIES.

For 10 years or more coke was made at Cambria, Wyo. In 1891, 24 beehive ovens were built and in 1895 this number was increased to 74. The ovens were operated chiefly to utilize the slack coal produced in mining operations. None of this slack was cleaned or washed before coking. Following are statistics of the production of coke at Cambria:

Statistics of production of coke at Cambria, Wyo., from 1891 to 1900.[1]

	Coal used (short tons).	Coke produced (short tons).	Total value of coke at ovens.	Value of coke at ovens per ton.	Yield of coal in coke.
					Per cent.
1891	4,470	2,682	$8,046	$3.00	60
1892	0	0	0	0	0
1893	5,400	2,916	10,206	3.50	54
1894	8,685	4,352	15,232	3.50	50
1895	10,240	4,895	17,133	3.50	47.8
1896	41,038	19,542	58,626	3.00	47.6
1897	54,976	24,007	72,021	3.00	43.7
1898	35,384	18,350	64,225	3.50	51.9
1899	32,100	15,630	38,510	2.46	48.7
1900	32,460	14,501	43,503	3.00	44.7

[1] Mineral Resources U. S. for 1900, U. S. Geol. Survey, 1901, p. 535.

The coke ovens at Cambria are located on the valley bottom about one-fourth mile below the tipple and were charged with slack coal brought from the tipple by narrow gauge tram to the top of the ovens. Three-ton charges were used for 48-hour firings and 5-ton charges for 72-hour firings. All coke produced was sold to smelters in the northern Black Hills; soon after the smelters closed the production of coke at Cambria was stopped and the ovens have been idle since 1903.

The coal produces a hard, compact coke, bright and metallic in color, and having high resistance to crushing load. It is suited for blast-furnace fuel, its only drawback being its high percentage of ash. For smelting precious metal it is especially desirable if, as reported (p. 63), it contains appreciable percentages of gold and silver.

The coking quality of coal can be determined with a fair degree of certainty by a simple physical test, called, from its discoverer, the Pishel test.[1] On grinding finely in an agate mortar coking coal will adhere strongly to the mortar and pestle; noncoking coal will not adhere. This test, applied to samples from the Cambria bed, shows that the bright bituminous coal has good coking quality but that the splint and cannel have not. Further testing shows that the bright jet-black bands of bituminous coal one-eighth to one-half inch thick found in the noncoking bituminous and splint coal adhere strongly to the mortar and have superior coking qualities. From the fact that slack from the Cambria mines makes good coke, except that it is high in ash, and from the fact that tests show the coking qualities of the bright bituminous coal to be superior to those of the other grades in the same bed, it is assumed that a better grade of coke could be produced by sorting run-of-mine coal and selecting that best for coking. Omitting the cannel and splint would certainly lower the percentage of ash.

An average of eight tests for ash in this coke is reported by the owners as giving 22.40 per cent. Probably the difference in specific gravity between the pure coal and the splint or cannel is not sufficient for thorough separation by washing or dry concentration. The price of coke would not warrant the expense of hand picking.

Agate-mortar tests of the coal at Holwell's on Skull Creek show that the benches of bright bituminous coal probably will coke well, but that the splint and cannel alone would coke poorly if at all. By the same test it is concluded that the upper half of the main bed at Aladdin is coking coal, but that the lower half is not. An actual coking test of Aladdin run-of-mine coal finely crushed and fired for 27 hours in a coke oven at the St. Louis fuel-testing plant produced no coke.[2] This result probably was due to the noncoking ashy coal which constitutes the lower half of the bed and consequently formed about 50 per cent of the run-of-mine shipment. If the bright coal only should be tested in an oven, the writer believes a good grade of coke would be produced. For best results the coal should be finely crushed before delivery to the ovens.

CHEMICAL PROPERTIES.

SELECTION OF SAMPLES.

During the operation of the Government fuel-testing plant at St. Louis, Mo., a car of run-of-mine coal was shipped from Aladdin under the direction of M. R. Campbell and two mine samples for chemical analysis were taken by him at working faces in the mine. Frank W.

---

[1] Practical test for coking coal: Econ. Geology, vol. 3, No. 4, June–July, 1908, pp. 265–275.

[2] Holmes, J. A., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: Bull. U. S. Geol. Survey, No. 290, 1906, p. 229.

DeWolf procured the shipment of a car of the commercial grade of engine coal produced at Cambria, which is a run-of-mine crushed and screened over a ¼-inch screen, and also obtained two mine samples by making cuts from roof to floor of the bed.

For the purpose of comparison and classification, the writer took separate samples at Aladdin, Holwell's, and Cambria of the different benches of the beds there developed.

All of these samples were collected in a uniform manner in accordance with the following instructions for coal sampling:

> Select a clean face of coal and across the bed from top to bottom cut a channel of sufficient depth to obtain 5 pounds of coal for each foot of bed, discard all partings more than one-fourth inch thick and lenses or concretions more than 2 inches in diameter and one-half inch in thickness. The material thus obtained should be caught upon canvas or oilcloth to exclude dirt and excess moisture.
>
> The sample thus obtained should be pulverized, in the mine if possible, until none of the fragments exceed one-half inch in diameter. The coal should then be mixed thoroughly and divided into four quarters, the two opposite discarded, and the remaining two mixed and quartered again. This process should be continued until the final sample is reduced to about 1 quart, which is to be placed in a can, sealed air-tight, and sent to the laboratory for analysis.

This method, used by all members of the Survey in such work, assures uniform and fairly representative samples, and the sealing of the cans insures the coal reaching the laboratory practically unchanged as regards its moisture content.[1]

COMPOSITION.

The few analyses of Black Hills coal that have been made by the survey are given in the table on page 53. Four analyses of a single sample are given. The analysis of air-dried coal is more nearly representative of the coal as it reaches the consumer, as a considerable percentage of the moisture is lost after mining.

---

[1] For a detailed description of the methods employed in the chemical analysis of coals, see: Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906.

Analyses of coal samples from the Black Hills coal field, Wyoming.

[F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.		Described on page—
	Quarter.	Sec.	T. N.	R. W.			Moisture.	Volatile matter.	Fixed carbon	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
1376	SE....	19	46	61	4.7	As received..........	8.6	37.1	32.4	21.9	4.94	....	....	....	....	5,395	9,710	37
	NW...	29	46	61	....	Air dried............	4.0	39.0	34.0	23.0	5.18	....	....	....	....	5,660	10,190	
						Dry coal............	....	40.6	35.4	24.0	5.40	....	....	....	....	5,900	10,620	
						Pure coal............	....	53.4	46.6	....	7.11	....	....	....	....	7,760	13,970	
1377	SE....	20	46	61	3.8	As received..........	9.2	36.1	33.7	21.0	4.33	....	....	....	....	....	....	37
						Air dried............	5.6	37.5	35.1	21.8	4.50	....	....	....	....	....	....	
						Dry coal............	....	39.7	37.2	23.1	4.77	....	....	....	....	....	....	
						Pure coal............	....	51.7	48.3	....	6.20	....	....	....	....	....	....	
1571	....	....	....	....	6.9	As received..........	9.5	35.0	34.8	20.72	3.91	5.00	51.46	0.74	18.17	5,360	9,650	37
						Air dried............	2.7	37.6	37.4	22.26	4.17	4.54	55.29	.80	12.94	5,760	10,360	
						Dry coal............	....	38.7	38.4	22.88	4.29	4.36	56.84	.82	10.81	5,920	10,660	
						Pure coal............	....	50.1	49.9	....	5.56	5.66	73.70	1.06	14.02	7,675	13,820	
6793	....	19	46	61	7.2	As received..........	9.8	41.0	40.9	8.31	4.44	5.69	62.02	.72	18.82	6,400	11,520	38
						Air dried............	2.8	44.2	44.0	8.96	4.78	5.27	66.83	.78	13.38	6,895	12,410	
						Dry coal............	....	45.5	45.3	9.22	4.92	5.10	68.79	.80	11.17	7,095	12,770	
						Pure coal............	....	50.1	49.9	....	5.42	5.62	75.78	.88	12.30	7,815	14,070	
6790	....	19	46	61	4.6	As received..........	6.6	35.3	33.3	24.78	4.38	4.76	51.16	.63	14.29	5,320	9,580	37
						Air dried............	2.0	37.0	35.0	25.97	4.59	4.46	53.63	.66	10.69	5,575	10,040	
						Dry coal............	....	37.8	35.7	26.52	4.69	4.31	54.75	.67	9.06	5,695	10,250	
						Pure coal............	....	51.4	48.6	....	6.38	5.87	74.51	.91	12.33	7,750	13,950	
6792	....	19	46	61	11.8	As received..........	14.1	34.1	36.6	15.19	4.42	5.54	52.20	.56	22.09	5,410	9,740	37
						Air dried............	2.5	38.7	41.6	17.22	5.01	4.79	59.19	.64	13.15	6,135	11,050	
						Dry coal............	....	39.7	42.6	17.67	5.14	4.63	60.73	.65	11.18	6,295	11,330	
						Pure coal............	....	48.2	51.8	....	6.24	5.62	73.76	.79	13.59	7,645	13,760	
6745	SE....	31	48	62	10.5	As received..........	14.4	26.0	37.8	21.8	3.10	....	....	....	....	....	....	29
						Air dried............	4.3	29.0	42.3	24.4	3.40	....	....	....	....	....	....	
						Dry coal............	....	30.3	44.2	25.5	3.62	....	....	....	....	....	....	
						Pure coal............	....	40.7	59.3	....	4.86	....	....	....	....	....	....	

Analyses of coal samples from the Black Hills coal field, Wyoming—Continued.

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.		Described on page—
	Quarter.	Sec.	T. N.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
6747	SE....	31	48	62	15.3	As received..........	20.4	26.7	34.8	18.1	....	....	....	....	....	....	....	28
						Air dried..........	6.0	31.6	41.1	21.3	....	....	....	....	....	....	....	
						Dry coal..........	....	33.6	43.7	22.7	....	....	....	....	....	....	....	
						Pure coal..........	....	43.5	56.5	....	....	....	....	....	....	....	....	
6743	SE....	31	48	62	10.7	As received..........	14.0	23.8	38.0	24.16	2.11	4.78	46.78	.63	21.54	4,570	8,230	28
						Air dried..........	3.6	26.7	42.6	27.06	2.36	4.02	52.38	.70	13.48	5,120	9,220	
						Dry coal..........	....	27.7	44.2	28.08	2.45	3.75	54.38	.73	10.61	5,315	9,560	
						Pure coal..........	....	38.5	61.5	....	3.41	5.21	75.61	1.01	14.76	7,390	13,300	
6744	SE....	31	48	62	14.1	As received..........	18.1	20.8	29.3	31.8	1.28	....	....	....	....	....	....	28
						Air dried..........	4.7	24.2	34.1	37.0	1.49	....	....	....	....	....	....	
						Dry coal..........	....	25.4	35.7	38.9	1.56	....	....	....	....	....	....	
						Pure coal..........	....	41.5	58.5	....	2.55	....	....	....	....	....	....	
6746	SE....	31	48	62	12.6	As received..........	16.8	38.7	39.5	4.96	3.57	6.33	57.55	.63	26.96	5,900	10,620	28
						Air dried..........	4.8	44.3	45.2	5.68	4.09	5.64	65.85	.72	18.02	6,750	12,150	
						Dry coal..........	....	46.5	47.5	5.96	4.29	5.36	69.21	.76	14.42	7,100	12,770	
						Pure coal..........	....	49.5	50.5	....	4.56	5.70	73.60	.81	15.33	7,545	13,580	
1976	....	27	54	61	11.8	As received..........	17.7	37.6	33.1	11.6	7.03	....	....	....	....	5,295	9,530	20
						Air dried..........	6.7	42.7	37.5	13.1	7.97	....	....	....	....	6,000	10,800	
						Dry coal..........	....	45.8	40.2	14.0	8.55	....	....	....	....	6,435	11,580	
						Pure coal..........	....	53.2	46.8	....	9.94	....	....	....	....	7,485	13,470	
1977	....	27	54	61	2.9	As received..........	18.4	36.5	35.0	10.1	6.73	....	....	....	....	....	....	20
						Air dried..........	7.3	41.5	39.7	11.5	7.64	....	....	....	....	....	....	
						Dry coal..........	....	44.8	42.8	12.4	8.25	....	....	....	....	....	....	
						Pure coal..........	....	51.1	48.9	....	9.41	....	....	....	....	....	....	
2278	....	27	54	61	2.9	As received..........	15.1	34.4	33.8	16.70	6.66	5.20	48.16	.70	22.58	4,960	8,930	20
						Air dried..........	12.6	35.4	34.8	17.20	6.86	5.08	49.60	.72	20.59	5,110	9,190	
						Dry coal..........	....	40.5	39.8	19.67	7.85	4.15	56.74	.82	10.77	5,840	10,520	
						Pure coal..........	....	50.4	49.6	....	9.77	5.17	70.63	1.02	13.41	7,275	13,090	

9320	....	27	54	61	13.1	As received..........	17.8	37.6	39.5	5.11	5.60	5.94	55.69	.89	26.77	5,615	10,110	20
						Air dried............	5.4	43.2	45.5	5.88	6.45	5.16	64.08	1.02	17.41	6,460	11,630	
						Dry coal.............	....	45.7	48.1	6.21	6.81	4.83	67.73	1.08	13.34	6,830	12,290	
						Pure coal............	....	48.7	51.3	....	7.26	5.15	72.22	1.15	14.22	7,280	13,100	
9321	....	27	54	61	9.7	As received.........	14.0	a36.8	38.3	10.93	4.97	6.60	55.94	.85	21.31	5,740	10,330	20
						Air dried............	4.8	40.7	42.4	12.10	5.51	5.45	61.95	.94	14.05	6,355	11,440	
						Dry coal.............	....	42.8	44.5	12.71	5.78	5.16	65.07	.99	10.29	6,675	12,020	
						Pure coal............	....	49.0	51.0	....	6.62	5.91	74.55	1.14	11.78	7,650	13,770	
10410	NE...	29	49	63	7.7	As received..........	11.6	33.1	34.0	21.30	2.64	5.24	50.05	.78	19.99	5,010	9,020	25
						Air dried............	4.2	35.9	36.8	23.08	2.86	4.74	54.22	.84	14.26	5,430	9,770	
						Dry coal.............	....	37.4	38.5	24.09	2.99	4.47	56.61	.88	10.96	5,665	10,200	
						Pure coal............	....	49.3	50.7	....	3.94	5.89	74.57	1.16	14.44	7,465	13,440	

a By modified method.

1376. Mine sample, Cambria, working face, whole bed, room 6 off third northwest entry, Antelope No. 3 and room 7 northwest, Antelope No. 1, mixed. F. W. De Wolf, 1905.

1377. Mine sample, Cambria, working face, whole bed, room 9 off the eighth northwest entry in Jumbo mine. F. W. De Wolf, 1905.

1571. Car sample, Cambria, used for gas-producer test.

6793. Hand-selected sample, best bituminous, Cambria, fresh mined, taken from cars as delivered at tipple, Antelope mines. R. W. Stone, November 4, 1908.

6790. Hand-selected sample, splint, Cambria, fresh mined, taken from cars as delivered at tipple, Antelope mines. R. W. Stone, November 4, 1908.

6792. Bin sample of slack from crusher, Cambria, used under boilers at mine. R. W. Stone, November 4, 1908.

6745. Mine sample, Holwell's, Skull Creek, face of 95-foot drift, not worked recently, whole bed. C. T. Lupton, October 25, 1908.

6747. Mine sample, Holwell's, Skull Creek, face of 55-foot drift, not worked recently, whole bed. C. T. Lupton, October 25, 1908.

6743. Mine sample, Holwell's, Skull Creek, face of 55-foot drift, not worked recently; cannel, middle bench. C. T. Lupton, October 25, 1908.

6744. Mine sample, Holwell's, Skull Creek, face of 55-foot drift, not worked recently; top bench, splint or bone. C. T. Lupton, October 25, 1908.

6746. Mine sample, Holwell's, Skull Creek, face of 55-foot drift, not worked recently; best bituminous, two benches mixed. C. T. Lupton, October 25, 1908.

1976. Mine sample, Aladdin, first room off fourth east entry or second east in new works, 35 feet east of main entry and 75 feet from mouth of mine, whole bed. M. R. Campbell, August 10, 1905.

1977. Mine sample, Aladdin, end of No. 2 entry, 850 feet from mouth of mine, whole bed. M. R. Campbell, August 10, 1905.

2278. Car sample, Aladdin run-of-mine coal used for boiler test, August, 1905.

9320. Mine sample, Aladdin, working face 700 feet from entry, upper half of bed, best coal. R. W. Stone, June 29, 1909.

9321. Mine sample, Aladdin, working face 700 feet from entry; lower half of bed, splint or bony coal. R. W. Stone, June 29, 1909.

10410. Hand-selected sample, Miller mine, near Sheldon, fresh mined, cannel. Sample taken by Charles H. Miller, April, 1909.

The analyses given in the table show that moisture in air-dried samples of Black Hills coal ranges from 2 to 7.29 per cent. One exception to this is a car sample from Aladdin which showed 12 per cent moisture, although four mine samples from the same place, which should naturally have been practically the same, carried from 4 to 7.29 per cent moisture. The writer suspects that the air-drying loss for No. 2278 should be 12.90 instead of 2.90. If this is the case, the analyses of the coal air-dried, dry, and pure should be recalculated.

The Black Hills coal is a high-volatile fuel, the average percentage of volatile matter nearly equaling that of fixed carbon. From the seventeen analyses of air-dried coal given in the table it is found that the usual amount of volatile matter is 37 per cent for the field, and of the fixed carbon 39.34. The volatile matter ranges from 24.21 to 44.27 per cent, these two extremes being in different benches of the same bed at Holwell's. A considerable part of the fuel value of coal is contained in the volatile matter. Hydrogen exceeds carbon in heat value, and thereby raises the calorific value of coal above that of the contained carbon alone. Coals which contain a large proportion of volatile matter ignite easily and burn with long, often sooty, flames. Steaming with a high-volatile coal involves considerable waste, as unless used in a specially constructed furnace or fire box the combustion of the gases is likely to take place in the stack and its energy be lost.

Fixed carbon in these coals ranges from 34 to 45.5 per cent and averages 39.34 for the field. This is the principal fuel constituent and the most efficient of the heat-producing factors. Combustion takes place on the grate by chemical combination of the carbon with the oxygen of the air.

Ash is by no means insignificant in the Black Hills coal. The analyses show quantities from less than 6 per cent to more than 37 per cent. These extremes do not represent whole beds but kinds of coal, the former being a bench of the best bituminous and the latter a splint. Cannel coal in this field carries 23 to 27 per cent ash, while bituminous coking coal in an under or overlying bench of the same bed has only 6 to 8 per cent of ash. Being an inert constituent from a heating standpoint, so large a percentage of ash as some of the coal contains is very objectionable, both because ash clogs the grate and hinders free combustion of the coal and also because of the cost of transporting. The percentage of ash in the bed at Aladdin, according to three analyses of air-dried coal (1976, 1977, 2278) is nearly 14 per cent, although the better coal in the upper half of the bed has only about 6 per cent ash. At Cambria the ash seems to be over 22 per cent. This is shown by two analyses (1376, 1377) of samples from the whole bed, excluding clay partings, and by a car sample (1571). An analysis (6793) of the best coal from the Antelope mines, made from a hand-selected sample from cars as delivered at the tipple, gives only 9 per cent ash in air-dried coal, but splint or poor coal selected the same way shows 26 per cent ash. Hauling nearly a ton of ash for every 4 tons of coal would seem to be very near the limit of profitable transportation.

In the ultimate analyses the elements determined are sulphur, hydrogen, carbon, nitrogen, and oxygen. These were determined in more than half of the samples in the above list.

The presence of sulphur in coal is objectionable despite the fact that it is combustible and develops heat. Not only does it give an offensive odor on burning but it corrodes the metal parts of the furnace. In the manufacture of iron and steel and in other metalliferous processes sulphur in the coal has a detrimental effect. The percentage of sulphur in the Black Hills coal is about 2.79 at Holwell's, 4.7 at Cambria, and 6.84 at Aladdin.

Hydrogen is in part combined with oxygen in the form of water and is therefore not heat producing. The remaining disposable hydrogen, being free to combine with oxygen on combustion, is a source of heat.

Carbon, of course, is the principal fuel element.

Nitrogen has no heat-producing power and lacks affinity for the other elements.

The oxygen in the coal is so combined with other elements as to be nonproductive of heat, most of it being in combination with hydrogen to form water.

Calorific value, as shown by calories and British thermal units, furnishes the most satisfactory means of comparison that can be derived from laboratory tests. Knowing the heat value, the ash content, and the physical character of a coal, a general estimate can be made of the adaptability of a coal for different purposes. Statements of the meaning of the values and of the method of obtaining them have been published elsewhere [1] and need not be repeated here. So far as shown by the analyses, for all of which the heat values were not determined, the bright coal at Cambria and at Holwell's is the best or highest in calorific value and the cannel coal is the lowest.

TESTS.

AT THE U. S. GEOLOGICAL SURVEY FUEL-TESTING PLANT.

During the Louisiana Purchase Exposition and in subsequent months in 1904-5 the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., conducted a series of tests on a considerable number of coals from numerous coal fields in the United States. Among these coals were three from the State of Wyoming: No. 1, Monarch coal from Sheridan; No. 2, Lakota coal from Cambria; and

---

[1] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, pp. 179-184. Voorhees, S. S., Methods of testing coal: Proc. Am. Soc. Testing Mat., vol. 7, 1907, pp. 560-571. Bull. U. S. Geol. Survey No. 415, 1910, pp. 241-243.

No. 3, Lakota coal from Aladdin. The results of these tests were published in Professional Paper 48 and Bulletins 261 and 290 of the United States Geological Survey. The main points ascertained are summarized and tabulated in the following pages. For further details reference should be made to the reports mentioned above.

Steaming tests.

Factors in test.	Sheridan.	Cambria.				Aladdin.		
	63	61	196	210	213	211	212	223
Heating value of coal, B. t. u. per pound dry coal	11,947	10,897	10,888	11,261	10,751	10,519	10,517	12,641
Force of draft:								
Under stack damper. inch water..	0.62	0.49	0.59	0.68	0.63	0.63	0.45	0.59
Above fire.....do....	.23	.14	.19	.20	[a] .08	.28	[b] .01	.23
Furnace temperature.....°F..	....	....	1,960	2,007	2,228	1,917	2,142	....
Dry coal per square foot of grate surface per hour.....pounds..	22.60	26.51	22.61	25.66	32.58	18.96	26.07	20.0
Equivalent water evaporated per square foot of water-heating surface per hour.....pounds..	3.17	3.13	2.88	3.15	3.56	2.39	3.15	2.89
Percentage of rated horsepower of boiler developed.....pounds..	88.8	87.76	79.3	88.3	99.86	67.0	88.2	81.0
Water apparently evaporated per pound of coal as fired.....pounds..	4.58	4.41	4.83	5.30	4.72	5.12	4.96	5.54
Water evaporated from and at 212° F.:								
Per pound of coal as fired.pounds..	5.47	5.26	5.66	6.19	5.56	5.98	5.81	6.33
Per pound of dry coal.....do....	7.00	5.92	6.27	6.84	6.10	7.04	6.73	8.07
Per pound of combustible..do....	7.66	8.26	8.54	9.01	8.30	9.17	8.59	9.06
Efficiency of boiler, including grate, per cent	54.89	52.46	55.61	58.66	54.79	64.63	61.80	61.06
Coal as fired:								
Per indicated horsepower hour, pounds	....	....	5.00	4.57	5.09	4.73	4.87	4.33
Per electrical horsepower hour, pounds	....	....	6.17	5.64	6.28	5.84	6.01	5.35
Dry coal:								
Per indicated horsepower hour, pounds	4.04	4.77	4.51	4.13	4.64	4.02	4.20	3.59
Per electrical horsepower hour, pounds	4.99	5.9	5.57	5.10	5.72	4.96	5.19	4.23

[a] Forced draft.

[b] Natural and forced draft.

Analyses of coal used for steaming tests.

Constituents.	Sheridan.	Cambria.				Aladdin.		
	63	61	196	210	213	211	212	223
PROXIMATE.								
Moisture	21.81	11.10	9.64	9.55	8.94	15.12	13.60	19.08
Volatile matter	40.56	35.55	34.75	35.75	35.90	34.36	36.12	36.58
Fixed carbon	31.61	34.58	34.68	35.73	33.70	33.82	34.07	37.56
Ash	6.02	18.77	20.93	18.97	21.46	16.70	16.21	6.78
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	.68	3.87	4.32	3.96	5.03	6.66	7.90	4.26
ULTIMATE.								
Carbon [a]	60.46	58.16	58.01	60.09	57.08	56.73	56.44	67.69
Hydrogen [a]	4.90	4.47	4.28	4.39	4.16	4.15	4.12	4.94
Oxygen [a]	15.83	11.07	8.93	9.25	8.80	10.77	10.72	12.86
Nitrogen [a]	1.30	.84	.89	.92	.87	.88	.82	.90
Sulphur	.81	4.35	4.78	4.37	5.52	7.85	9.14	5.28
Ash	7.70	21.11	23.16	20.98	23.57	19.67	18.76	8.28

[a] Figured from car sample.

Coal consumed in producer-gas tests in pounds per hour.

	Cambria (No. 16).			Cambria (No. 62).			Aladdin (No. 69).		
	Coal as fired.	Dry coal.	Combustible.	Coal as fired.	Dry coal.	Combustible.	Coal as fired.	Dry coal.	Combustible.
In producer.									
Per electrical horsepower:									
Available for outside purposes	2.18	1.98	1.52	2.28	2.08	1.59	2.05	1.78	1.47
Developed at switchboard	2.00	1.82	1.40	2.16	1.97	1.50	1.92	1.67	1.37
Per brake horsepower:									
Available for outside purposes	1.86	1.68	1.30	1.98	1.77	1.35	1.74	1.52	1.25
Developed at engine	1.70	1.54	1.19	1.83	1.68	1.28	1.63	1.42	1.17
In producer plant.									
Per electrical horsepower:									
Available for outside purposes	2.49	2.25	1.74	2.40	2.20	1.68	2.19	1.90	1.57
Developed at switchboard	2.28	2.07	1.60	2.28	2.09	1.59	2.04	1.78	1.46
Per brake horsepower:									
Available for outside purposes	2.11	1.92	1.48	2.05	1.87	1.43	1.86	1.62	1.33
Developed at engine	1.94	1.76	1.36	1.94	1.77	1.35	1.74	1.51	1.24
Average electrical horsepower	201.2			192.9			193.1		
Average B. t. u. gas, per cubic foot	151			146.6			160.9		
Total coal fired, pounds	12,100			20,400			17,400		

Analyses of coal used in producer-gas test and of gas produced.

Constituents.	Cambria.		Aladdin.
	16	62	69
Coal.			
Moisture	9.44	8.63	13.02
Volatile matter	35.02	36.81	37.56
Fixed carbon	34.82	32.83	34.05
Ash	20.72	21.73	15.37
Sulphur	3.91	4.47	7.36
Gas by volume.			
Carbon dioxide	10.21	10.8	11.1
Oxygen	.59	....	....
Carbon monoxide	15.46	18.2	19.8
Hydrogen	10.79	10.7	13.3
Methane	5.52	3.3	3.5
Nitrogen	57.48	57.0	52.3

Washing test.

[Test 129, Wyoming No. 3 (Aladdin). Size as shipped, run of mine; size as used, crushed to 2 inches Jig used, Stewart modified.]

Raw coal	pounds	24,120
Washed coal	do	20,060
Refuse	do	4,060

Analyses.

Constituents.	Test 129.	
	Raw coal.	Washed coal.
Moisture	15.12	19.16
Volatile matter	34.36	....
Fixed carbon	33.82	....
Ash	16.70	6.52
Sulphur	6.66	4.16

Coking test.

[Test 52, Wyoming No. 3 (Aladdin), washed. Size as shipped, run of mine; size as used, finely crushed. Duration of test, 27 hours.]

No coke produced.

The following statements concerning the results of these tests were published in the report of the coal-testing plant:[1]

> The results obtained on the coal from Cambria are lower than those from the Sheridan lignite, but this is due in large measure to the heavy percentage of ash that is carried by the Cambria coal. The recalculated analysis, in which the ash is thrown out, shows that the Cambria coal is superior to the other.
>
> Some briquetting tests were made on these samples, but they gave no promise of success in a commercial way.
>
> The best results were obtained by using this coal (Cambria) in the producer-gas plant. The results show that with the (Wyoming No. 2) Cambria coal it required 2.07 pounds of dry coal to produce one electrical horsepower hour, whereas when used in the steam plant it required 5.9 pounds of dry coal to produce the same result. It is probable that equally good or better results could have been obtained with Wyoming No. 1 (Sheridan coal at Monarch), since in general the quality of the gas improves as one descends in the scale of quality of coal, the best results being obtained from brown lignite.

Of the results when Cambria coal was used in the gas-producer engine, the following was said:[2]

> Wyoming No. 2 is a bituminous coal. It burned without any clinkering, leaving a large amount of white ash similar to that obtained from wood. The gas was not uniform in quality, on account of the difficulty experienced in keeping the bed in good condition, which made more or less trouble in securing the proper mixture of air and gas. There was also some slight trouble with the ignition setting. Sixty gallons of yellow tar were taken from the gas.

MISCELLANEOUS TESTS.

The results of boiler tests of the Cambria coal made by the Cambria Fuel Co., at Cambria, Wyo., and by the Lincoln Traction Co., Lincoln, Nebr., have been furnished by the respective companies and are given below for comparison with the results of the Government tests.

---

[1] Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Report of the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper, U. S. Geol. Survey No. 48, 1906, pt. 1, p. 141.

[2] Idem, pt. 3, p. 1314.

Results of evaporative tests of Cambria coal.

[Made by the Cambria Fuel Co., Cambria, Wyo.]

Test made on	No. 6 boiler, Heine tubular	No. 8 boiler, Heine tubular.
Kind of fuel	Splint and screenings	Splint and screenings.
Kind of furnace	Hand-fire grates	One 10-inch American stoker.
Water-heating surface, square feet	1,786.5	1,609.5.
1. Date of trial, 1907	June 22	June 21.
2. Duration of trial, hours	8	8.
3. Weight of coal fired, pounds	11,250	7,125.
4. Total weight water fed to boiler, do	46,357	36,560.
5. Equivalent water evaporated from and at 212° F, pounds	55,211	43,506.
6. Coal consumed per hour, do	1,406	890.
7. Water evaporated per hour from and at 212° F, pounds	6,901.4	5,438.3.
8. Equivalent evaporation from and at 212° F. per square foot of water-heating surface, pounds	3.86	3.37.
9. Steam pressure (gauge), pounds per square inch	99.7	95.5.
10. Temperature of water entering boiler, °F.	66.75	66.
11. Factor of evaporation from and at 212°F.	1.191	1.19.
12. Pressure of blast under furnace, inches water	3	3.
13. Horsepower developed	200.4	157.6.
14. Builder's rated horsepower	150	135.
15. Per cent of builder's horsepower developed	133.6	116.
16. Water apparently evaporated under actual conditions per pound of coal as fired, pounds	4.12	5.13.
17. Equivalent evaporation from and at 212° per pound of coal as fired, pounds	4.91	6.10.

NOTE.—(1) Capacity obtained in excess of guarantee, 16 per cent; (2) economy obtained, stoker firing over hand firing, in excess of guarantee, 22.4 per cent. Test made by Gordon L. Huchins, M. E.

Boiler tests made by Lincoln Traction Co., Lincoln, Nebr., on Cambria and Weir-Pittsburg coals.

	Cambria, Wyo., coal.			Weir-Pittsburg, Kans., coal.	
	1	2	3	1	2
Date of trial, 1904	Nov. 23	Nov. 25	Nov. 30	Dec. 3	Dec. 5
Duration of trial, hours	10	10	10	10	10
Babcock & Wilcox battery	No. 1-3-4	No. 1-3-4	No. 1-3-4	No. 1-3-4	No. 1-2-4
Weight of coal as fired, pounds	37,845	48,000	45,850	41,400	42,100
Total weight of water fed to boiler, do	195,500	242,029	245,848	273,390	265,200
Factor of evaporation	1.1066	1.1191	1.1128	1.126	1.1285
Equivalent water evaporated into steam from and at 212° F, pounds	216,340	270,854	273,579	307,837	299,278
Steam pressure by gage, do	140	140	140	135	140
Temperature of feed water, ° F.	155	143	149	135	133
Water apparently evaporated under actual conditions per pound of coal as fired, pounds	5.16	5.04	5.36	6.6	6.3
Equivalent evaporation from and at 212° F. per pound of coal as fired, pounds	5.72	5.64	5.96	7.43	7.1
Total weight of ashes removed, do		8,837	9,120	5,514	7,800
Ash, per cent		18	20	13.3	18.5
Cost of coal per ton (delivered)	$2.05	$2.05	$2.05	$2.35	$2.35
Cost of coal to evaporate 1,000 pounds of water	$0.179	$0.182	$0.172	$0.158	$0.165

A test made at the municipal pumping station, Hastings, Nebr., to determine the comparative efficiency and cost of several available coals showed best results with Cambria coal. The results of the tests, as sworn to by E. J. Peare and H. W. Main to the mayor and council of Hastings, are given in the following table:

Tests of different coals made at municipal pumping station, Hastings, Nebr.

	Cambria, Wyo., steam.	Sheridan, Wyo., lump.	Bevier, Mo., steam.	Rich Hill, Mo., mixture.	Muchakinock, Iowa, steam.
Date.........................1896..	Aug. 13-15	Aug. 25-27	Aug. 28-29	Aug. 21-Sept. 2	Sept. 3-5
Strokes of pump....................	53,927	40.598	33,580	51,704	48,244
Water pumped............gallons..	970,686	730,764	604.440	930,672	868.302
Coal consumed............pounds..	29,853	25,947	23,436	30,690	32,922
Water pumped per pound of coal.......................gallons..	32½	28⅛	25¾	30⅓	26⅜
Cost of pumping 100,000 gallons.....	$4.15	$5.77	$5.30	$4.70	$4.99

SUMMARY OF TESTS.

The foregoing tests and analyses show somewhat conflicting results concerning the value and efficiency of the Black Hills coals when compared with competing coals. The high percentage of ash in the coal mined at Cambria and Aladdin is about counterbalanced by the high percentage of moisture in that mined at Sheridan. When compared on a pure-coal basis (ash and moisture free), the Black Hills coal is superior, but if comparative producer-gas tests were available the Sheridan coal would undoubtedly be found more efficient. For steaming there is little preference between Black Hills and Sheridan coal. In the foregoing tables this is shown by a comparison of the number of pounds of water apparently evaporated per pound of coal as fired. It may be summarized thus:

Water evaporated per pound of coal fired.

	Pounds.
Sheridan coal (1 test)..	4.58
Cambria coal (average of 9 tests)................................	4.89
Aladdin coal (average of 3 tests)................................	5.20

The writer believes that the comparative value of coals competing with Cambria coal is fairly well expressed by T. J. Grier, superintendent of the Homestake Mining Co., Lead, S. Dak., who said, in writing of results obtained at the Homestake mine, which uses about 225 tons of coal daily: "The coals weighed were Glenrock, Fetterman, Hanna, Cambria, Sheridan, and Monarch, and the results obtained did not seem to show any more difference in fuel value than would be made by a careful fireman as compared with one who was not so careful." Under these conditions where competing coals of different character have practically the same fuel value the factors determining which shall be used are constancy of supply and cost per ton delivered. Freight rates affect cost very materially.

GOLD IN CAMBRIA COAL.

An interesting feature about the Cambria coal is that it is said to be gold bearing. According to a verbal statement by W. E. Mouck, superintendent of the Cambria mines, an assay made by the company's chemist of ashes from the boiler house showed $10 per ton and of the sandstone roof of the bed $2 per ton in gold. This unexpected result led to further investigation, and soot from the furnace stack was assayed, with the result that it was found to contain $4 per ton in gold. The coal itself has shown from nothing up to $2 per ton in gold when the coal was selling for $1.50. In 1896, when coke made at Cambria was selling for $3.50 per ton, samples were taken from 31 cars during a period of three weeks and were assayed by the company's chemist. The samples from 31 cars of coke showed an average of $2.46 per ton in gold and $0.28 in silver. The following results of these assays were kindly furnished by the Cambria Fuel Co.:

Gold and silver assays of coke made from Cambria coal.

[Values per ton.]

Date.	Sample from Burlington & Missouri River R.R. car No. —	Gold.[a]	Silver.[b]	Total.
1896				
July 18	3671	$2.00	$0.08	$2.08
18	3871	2.40	.12	2.52
25	3711	2.00	.08	2.08
25	3761	3.60	.00	3.60
25	3693	2.40	.13	2.53
28	2835	2.80	.30	3.10
28	3691	3.20	.40	3.60
28	3806	2.40	.34	2.74
28	3887	2.00	.46	2.46
28	4013	2.00	.47	2.47
28	3801	2.00	.47	2.47
28	3855	2.60	.34	2.94
28	3947	3.60	.65	4.25
28	3871	2.40	.46	2.86
28	3763	2.00	.41	2.41
30	3695	5.60	.21	5.81
30	1859	3.20	.16	3.36
31	3761	2.00	.41	2.41
Aug. 3	3711	2.00	.34	2.34
3	3691	2.20	.42	2.62
3	3859	2.00	.37	2.37
5	3887	2.00	.00	2.00
5	3695	2.20	.21	2.41
5	4013	2.00	.14	2.14
6	3855	2.00	.43	2.43
6	3835	2.40	.39	2.79
8	3801	2.00	.10	2.10
8	4015	2.40	.20	2.60
8	3685	2.00	.16	2.16
8	3813	2.80	.16	2.96
8	3671	2.20	.14	2.34
Average (31 cars)		2.46	.28	2.74

[a] Valued at $20 per ounce.

[b] Valued at $0.65 per ounce.

Henry C. Beeler, chemist, Cambria, Wyo., August 8, 1896.

Smelters at Deadwood, S. Dak., which used the Cambria coke, must have profited by it, for they recovered not only the gold in their ores, but the gold from the coke also.

Gold was found in some of the coal from the Jumbo mine and the Antelope mines 1 and 2. The distribution of the gold in the mines was never determined. There is more gold in the splint and bony coal than in the best bituminous. It may be associated with pyrites, which occurs commonly in the splint and "pine needle" coal.

As there are no known dikes or veins within many miles of the coal mine at Cambria, the gold can not be explained as derived from such a source. That the gold was introduced in the quiet waters of the swamp, either in solution or as very fine particles in suspension, and deposited there by precipitation or by gravity is not impossible nor yet readily conceivable; first, because it is presumed that the water discharged into the swamp was comparatively fresh meteoric water and would not have dissolved gold; second, because drainage in and around a large swamp is very sluggish. Under such topographic conditions it is hardly probable that even fine gold would reach and be distributed in a large swamp. The most plausible explanation seems to be that the sands which submerged the swamp and now form the roof of the coal bed were derived in part from old gold-bearing alluvium. It was noted above that the sandstone roof carries some gold. Currents which transported the sand and the grit which occurs in some places a few feet above the coal certainly were strong enough to transport fine gold. While the sand was being deposited the gold may have worked down into the underlying bog and is now found in the coal.

PROSPECTS FOR THE FUTURE.

From the evidence it seems to the writer that the acreage of coal near Cambria as yet untouched is sufficient to keep the mines there in operation for many years at the present rate of output. It is possible that a body of coal large enough to warrant the opening of a mine may be found at the Holwell ranch, but this has not been proved and is seriously questioned; moreover, until a railroad is built down Skull Creek there is no reason for opening a mine at Holwell's, as there is no demand for coal in that region. At none of the other places between Aladdin and Edgemont where coal has been found did the writer see enough good coal to suggest that any of them would ever supply a tonnage worthy of record. It is possible that at some points coal may be taken for local ranch use, but that any of the localities besides Cambria will ever in future add to the State's record of coal produced and shipped is doubted.

INDEX.

Page.

Acknowledgments to those aiding........... 7

Aladdin, coal and sandstone near, sections of. 15, 21

  coal near, analyses of................. 20, 54-55

    character and occurrence of......... 18-21

    tests of........................... 58-60, 62

  Lakota sandstone at, plate showing..... 18

  mines and prospects near, figure showing 19

    output of........................... 20

  sections near......................... 15, 16, 21

  Stilwell Co.'s mine at, plate showing..... 18

Analyses, of Black Hills coal, tables showing.. 53-55

Antelope mines, sections of coal beds in...... 35-36

  See also Cambria.

Bevier coal, test of.......................... 62

Bibliography of Black Hills coal resources.... 5-6

Black Hills, coal of, analyses of.............. 53-57

  coal of, character and distribution of...... 17-64

    chemical properties of............... 51-52

    coking qualities of................ 50-51, 60

    occurrence of......................... 17-48

    physical properties of................ 48-50

    production of..................... 20, 42, 64

    sections of, plate showing............ 34

    tests of.............................. 57-62

  general map of.......................... 6

  geology of.............................. 7-17

  location and topography of............. 7

  stratigraphy of......................... 8-17

  structure of............................ 7-8

Boiler tests, of Cambria and Weir-Pittsburgh coals, results of.................. 61

Cambria, coal from, analyses of............... 37, 53

  coal from, character and occurrence of.... 34-37

    tests of........................ 58-59, 61

  coke production of...................... 50-51

  development at.......................... 34

  Lakota sandstone near, plate showing.... 10

  mine and civic equipment of............. 38-42

  mine workings near, figure showing..... 33

  output of mines of...................... 42

  population and buildings of............. 38-39

  railroad facilities of.................. 39

  stratigraphic relations near............ 10-12

  view of, plate showing.................. 38

  water supply of......................... 39

Cambria Fuel Co., mining equipment of...... 39-42

  tipple of, plate showing................ 38

Camp Canyon, Lakota sandstone in, plate showing......................... 18

Cheyenne River, outcrops of coal along...... 45-47

  section of coal near, figure showing...... 47

Coal, analyses of........................... 53-57

  beds of, character, distribution, development and sections of.......... 17-48

    sections of, plate showing........... 34

Page.

Coal, character of............................ 48-64

  chemical properties of.................. 51-52

  coking qualities of.................... 50-51, 60

  gold in, occurrence of.................. 63-64

  physical properties of.................. 48-50

    plate illustrating.................... 48

  producer-gas tests of.................. 59

  production of......................... 20, 42, 64

  steaming tests of...................... 58

  tests of................................ 58-62

  washing tests of....................... 59

Coke, production of.......................... 50-51

Coking test, on Black Hills coal, results of..... 60

Dakota sandstone, character and thickness of. 16-17

  exposures of, plates showing............. 10, 16

  sections of.............................. 10-13

Dry Creek, section at prospect near.......... 27

East Plum Creek, sections of coal beds on.... 31

Edgemont, occurrence of coal near........... 45-47

  occurrence of coal near, figure showing.... 46

  section of coal near, figure showing........ 47

  sections near.......................... 15, 45, 47

Evaporative tests of Cambria coal, results of.. 61

Fuson shale, character and thickness of....... 15-16

  sections of.............................. 16, 27

Gold, in Cambria coal, occurrence and assays of.................................. 63-64

Graneros shale, character and occurrence of... 17

Grant Canyon, section of coal bed near........ 43

Hastings, Nebr., coal tests made at........... 62

Holwell ranch, occurrence of coal at........... 27-30

  prospects on, location of, figure showing.. 28

  sample of coal from, analysis of.......... 29, 53

  sections at.............................. 28, 29

Inyankara Mountain, supposed coal outcrop near................................ 24

Jumbo mine. *See* Cambria.

Lakota sandstone, character and occurrence of................................ 9-15

  exposures of, plates showing............. 10, 18

Lincoln Traction Co., boiler tests of coal by... 61

Little Oil Creek, occurrence of coal on......... 43-44

  sandstone exposure on, plate showing.... 10

  sections along........................... 11, 43

Lupton, C. T., report on Cambria by......... 38-42

Mason Creek, occurrence of coal on........... 24-27

Miller coal mine, development and section at. 24-25

Morrison shale, character and occurrence of... 9

Mount Zion ranch, occurrence of coal near.... 43

  opening on coal near, plate showing...... 42

  section of Lakota sandstone near......... 12

Newcastle coal, test of....................... 62

  Dakota sandstone near, plate showing.... 10

  prospects near, figure showing............ 28

  stratigraphic relations near.............. 11

Page.

Oil Creek, stratigraphic relations near........ 13-15
Philpott Canyon, occurrence of coal in....... 25-27
Plum Creek, occurrence of coal near......... 31-32
    stratigraphic relations near.............. 12
Producer-gas tests of Black Hills coal, results of............................... 59
Publications, on Black Hills coal............ 5-6
"Red beds," character and thickness of..... 9
Rich Hill coal, test of........................ 62
Robbersroost Canyon, coal prospect in...... 44
Salt Creek, coal beds near.................... 32, 44
Salt Spring, coal bed near.................... 32

Page.

Sheridan coal, tests of........................ 58, 62
Skull Creek, occurrence of coal along.......... 27-31
Spearfish formation, character and thickness of............................... 9
Spencer prospect, sections at................. 30
Steaming tests, of Black Hills coal, results of.. 58
Sundance, occurrence of coal near............ 21-24
    occurrence of coal near, figures showing... 22, 23
Sundance formation, character and thickness of............................... 9
Tests, of Black Hills coal, results of........... 57-62
Weir-Pittsburgh coal, boiler test of.......... 61

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 500

GEOLOGY AND COAL FIELDS
OF THE
LOWER MATANUSKA VALLEY
ALASKA

BY

G. C. MARTIN AND F. J. KATZ

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

CONTENTS.

Page.

Preface, by Alfred H. Brooks........ 7

Introduction........ 9

  Location........ 9

  Account of investigations........ 9

    Exploratory and reconnaissance surveys........ 9

    Detailed surveys........ 10

  General description of the district........ 10

    Geography........ 10

    Climate........ 11

    Vegetation........ 13

    Accessibility........ 13

    Commercial development........ 14

  Outline of the geology of the Matanuska Valley........ 14

    General features........ 14

    Mica schists........ 15

    Graywackes and slates of the Knik River region........ 16

    Lower Jurassic rocks........ 17

    Granitic rocks........ 19

    Middle and Upper Jurassic rocks........ 20

    Lower Cretaceous rocks........ 22

    Upper Cretaceous rocks........ 23

    Tertiary rocks........ 24

    Quaternary deposits........ 25

Detailed description of the rocks of the lower Matanuska Valley........ 26

  Granitic and gneissic rocks........ 26

    Areal distribution........ 26

    Lithologic character........ 27

    Age and relations........ 27

  Lower Jurassic rocks........ 29

    Volcanic breccia, agglomerate and tuff........ 29

      Areal distribution........ 29

      Lithologic character........ 29

      Fauna........ 30

      Age and correlation........ 31

  Lower Cretaceous (?) rocks........ 32

    Limestone........ 32

      Areal distribution........ 32

      Lithologic character........ 32

      Stratigraphic relations........ 33

      Age and correlation........ 33

  Upper Cretaceous rocks........ 34

    Areal distribution........ 34

    Lithologic character........ 34

    Fauna and flora........ 36

    Age and correlation........ 38

Detailed description of the rocks of the lower Matanuska Valley—Continued. Page.

- Tertiary rocks....................... 39
  - Arkose, conglomerate, and shale....................... 39
    - Areal distribution....................... 39
    - Lithologic character....................... 39
    - Stratigraphic relations....................... 41
    - Flora....................... 42
  - Chickaloon formation....................... 42
    - Areal distribution....................... 42
    - Lithologic character....................... 43
    - Flora and fauna....................... 49
    - Age and correlation....................... 52
  - Eska conglomerate....................... 52
    - Areal distribution....................... 52
    - Lithologic character....................... 53
    - Age and correlation....................... 54
  - Basaltic lavas and tuffs....................... 54
  - Tertiary intrusive rocks....................... 55
    - Diorite porphyries....................... 56
      - Areal distribution....................... 56
      - Petrographic character....................... 56
      - Local relations....................... 58
    - Trachytic rocks....................... 61
      - Areal distribution....................... 61
      - Petrographic character....................... 61
      - Local relations....................... 62
    - Diabase and gabbro....................... 63
      - Areal distribution....................... 63
      - Petrographic character....................... 63
      - Local relations....................... 64
- Quaternary deposits....................... 67
  - Morainic deposits....................... 68
  - Terrace gravels....................... 69
  - Alluvium....................... 71

Structure....................... 72

Mineral resources....................... 75

- Coal....................... 75
  - Areal distribution....................... 75
  - Stratigraphic occurrence....................... 77
  - Description of beds....................... 77
  - Character of the coal....................... 88
    - Physical properties....................... 88
    - Chemical analyses and tests....................... 89
    - Coking qualities....................... 92
  - Mining conditions....................... 92
    - Mine sites....................... 92
    - Local supplies....................... 93
    - Underground water and gas....................... 93
    - Effect of intrusive rocks....................... 93
    - Effect of folding and faulting....................... 94
- Metals....................... 95

Index....................... 97

ILLUSTRATIONS.

Page.

PLATE I. Map of central Alaska, showing position of the coal fields........ 10

II. *A*, Talkeetna Mountains from the west side of Kings River; *B*, North wall of Matanuska Valley about 12 miles above Chickaloon River........ 10

III. Geologic reconnaissance map of the Matanuska Valley....... In pocket.

IV. Topographic map of the lower Matanuska Valley............ In pocket.

V. Geologic map of the lower Matanuska Valley.............. In pocket.

VI. *A*, Granite and Tertiary arkose in gulch on the west side of Sheep Valley; *B*, Granite and Tertiary arkose in the west wall of Sheep Valley........ 28

VII. *A*, Granite overlain by arkose at the head of Sheep Valley; *B*, Sheep Valley from a point near its lower end........ 28

VIII. *A*, Exposure of arkose in cliffs on north slope of ridge north of Moose Creek; *B*, Gently dipping arkose in west end of ridge north of Moose Creek........ 40

IX. *A*, Eska conglomerate on west wall of valley of Eska Creek, at east end of Wishbone Hill; *B*, Eska conglomerate in west end of Castle Mountain........ 52

X. *A*, Tertiary lavas, unconformably overlying Eska conglomerate on Castle Mountain; *B*, Eska conglomerate overlain by small cap of Tertiary lava on southeast spur of Castle Mountain...... 56

XI. *A*, Porphyry sill (?) in valley of Young Creek overlying Chickaloon formation; *B*, Porphyry sills and dikes in Upper Cretaceous rocks on south bank of Matanuska River 2.7 miles below Chickaloon River........ 56

XII. *A*, Diabase dike on fault in Chickaloon formation at base of Castle Mountain; *B*, Diabase dikes and sills in Chickaloon formation on north bank of Boulder Creek........ 64

XIII. *A*, Stratified gravels on east bank of Kings River near lower bridge; *B*, Gravel cliffs on north bank of Matanuska River 1 mile above Moose Creek........ 70

XIV. *A*, Fault on north edge of Matanuska Valley near headwaters of Young Creek; *B*, Fault between granite and Upper Cretaceous rocks........ 72

XV. Structure sections in lower Matanuska Valley................ 72

XVI. Structure sections in lower Matanuska Valley................ 72

XVII. *A*, Coal beds in west bank of Eska Creek 2.7 miles north of Matanuska River; *B*, Coal bed in west bank of Eska Creek 2.4 miles north of Matanuska River........ 82

XVIII. Map showing coal areas, location of the coal sections, and localities from which samples were taken..................... In pocket.

XIX. *A*, Coal bed in west bank of Chickaloon River at bend above coal camp; *B*, Coal bed in east bank of Coal Creek seven-eighths of a mile above its mouth........ 92

Page
FIGURE 1. Columnar section in summit of Castle Mountain................ 55
2. Section in cliff on Young Creek showing relation of diorite porphyry to Tertiary sediments................................ 59
3. Section on Young Creek showing relation of diorite porphyry to Tertiary sediments.. 60
4. Folded beds of the Chickaloon formation and sill............... 61
5. Diabase sills and dikes in the Chickaloon formation near Chickaloon.. 65
6. Section at south base of Castle Mountain showing relation of gabbro to Tertiary sediments................................ [illegible]
7. Section along cliff on west bank of Chickaloon River, showing relation of diabase sills to Chickaloon formation.............. 66
8. Section in bank of creek 1¾ miles northwest of Chickaloon, showing relation of gabbro to Chickaloon formation................ 66
9. Section in cliff on east bank of Chickaloon River, showing relation of gabbro to Chickaloon formation....................... 67
10. Gabbro injected into shale, south of Boulder Creek............ 67
11. Diagram of terraces on Moose Creek and on Kings River......... 70
12. Sketch showing location of Chickaloon tunnels................. 78

PREFACE.

By ALFRED H. BROOKS.

In 1895 the Geological Survey made a preliminary investigation of the coals along the Pacific seaboard of Alaska. The report[1] published on this subject was the first of a large number which deal primarily or incidentally with the coal deposits of the Territory. In 1902 a systematic study was made of the coal resources of the Yukon.[2] This was followed in succeeding years by reconnaissance surveys of the coal resources of Admiralty Island,[3] in southeastern Alaska; of Kachemak Bay[4] (see Pl. I), of Cape Lisburne,[5] in northwestern Alaska, and of the Cook Inlet[6] and Alaska Peninsula regions.[7] In 1910 a reconnaissance survey of the Nenana coal field[8] was completed (Pl. I). Meanwhile the more valuable coal fields of Bering River and Matanuska Valley had not been neglected. A preliminary examination of the Bering field was made in 1903[9] and of the Matanuska field in 1905[10] and 1906.[11]

The plan of the Survey's Alaskan investigations includes the detailed survey of the most important mining districts. It is believed that so long as there are large areas geologically almost unknown, the detailed surveys, which are expensive of execution, should not be carried on at the cost of too great a curtailment of the reconnaissance work. It is for this reason that the detailed surveys have not been advanced more rapidly. Because of its earlier discovery and greater accessibility the Bering field was surveyed in detail before the Matanuska River field. This survey was completed in 1906.[12] In

---

[1] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 763-908.

[2] Collier, A. J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903.

[3] Wright, C. W., A reconnaissance of Admiralty Island: Bull. U. S. Geol. Survey No. 287, 1907, pp. 151-154.

[4] Stone, R. W., Coal fields of the Kachemak Bay region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 53-73.

[5] Collier, A. J., Geology and mineral resources of the Cape Lisburne region, Alaska: Bull. U. S. Geol. Survey No. 278, 1906.

[6] Atwood, W. W., Mineral resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 108-152.

[7] Atwood, W. W., Geology and mineral resources of parts of Alaska Peninsula: Bull. U. S. Geol. Survey No. 467, 1911.

[8] Capps, S. R., The Bonnifield region, Alaska: Bull. U. S. Geol. Survey No. 501, 1912.

[9] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: Bull. U. S. Geol. Survey No. 250, 1905.

[10] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906.

[11] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907.

[12] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: Bull. U. S. Geol. Survey No. 335, 1908.

1909 the detailed base map of the Matanuska field was prepared, and in 1910 the geologic investigations, whose results are here set forth, were completed. This report forms the second of a series which will set forth the detailed geology of the Alaskan coal fields. The detailed work in any particular field, on which such a report is necessarily based, will not be undertaken until there is promise that the field will be developed in a large way.

The detailed survey of the Matanuska field has fully justified its cost, if only from the fact that it has revealed a much larger area of supposed coal-bearing formations than was previously known. Previous to this survey the area underlain by supposed coal-bearing rocks was roughly estimated at about 50 square miles; now it is estimated to be at least 74 and possibly 98 square miles. (See p. 76.) It has not been determined that all of this area contains workable coal beds, but the survey indicates at least that the coal reserve in this field may be twice as large as previously estimated. In this connection it should be noted that coal is known to occur east of the field here discussed and the coal-bearing area may be considerably larger than is included in the above figures.

The best of the bituminous coals of this field are of the same grade as those of the Bering River field, but from the information at hand they seem to carry a larger percentage of fuels having coking qualities. It was a part of the original plan to have this investigation cover also the anthracite coal of the Matanuska Valley, but time did not permit.

In comparing the commercial value of the Bering River and Matanuska fields, in the matter of distance to tidewater the first has a decided advantage, being only 60 miles from Cordova and 25 from Controller Bay (Pl. I). On the other hand, the rocks in the best-known part of the Matanuska field seem to be less intricately folded than those of the Bering River field, a condition which makes for cheaper mining. Mr. Martin and Mr. Katz point out (pp. 94–95), to be sure, that the degree of folding in much of the Matanuska field must remain in a large measure unknown until more underground explorations have been made, but this is also true of the Bering River field. If the deformation of the Matanuska field proves to be less intense than that of the Bering River field, this advantage may be in a measure offset by the fact that mining in the Matanuska will be rendered more expensive because of the presence of considerable igneous rock, which is almost entirely absent from the other field. All this points to the necessity of careful and systematic prospecting of each coal tract before any large amount of money is expended on equipment.

GEOLOGY AND COAL FIELDS OF THE LOWER MATANUSKA VALLEY, ALASKA.

By G. C. Martin and F. J. Katz.

INTRODUCTION.

LOCATION.

The area described in this report covers about 200 square miles and is situated in the lower part of the Matanuska Valley, in the south-central part of Alaska. It is about 25 to 50 miles northeast of tidewater at the head of Cook Inlet and about 100 miles north of Seward, which is the nearest large town and the nearest ocean port. (See Pl. I.)

ACCOUNT OF INVESTIGATIONS.

EXPLORATORY AND RECONNAISSANCE SURVEYS.

The investigations which were made with the purpose of preparing this report were preceded by other surveys through which the general features of this district have already been made known and which have contributed in no small degree to the results presented below.

The Matanuska Valley was traversed in 1898 by W. C. Mendenhall, who was attached as geologist to "military expedition No. 3" in charge of Capt. Edwin F. Glenn, Twenty-fifth Infantry, United States Army. Mendenhall's explorations covered areas on the west shore of Prince William Sound and a route extending from Resurrection Bay to the head of Turnagain Arm, thence by way of Glacier and Yukla Creeks to Knik Arm, up the Matanuska Valley to its head, and thence northward to the Tanana. Mendenhall's account[1] of his explorations includes a description of the general geologic and geographic features, accompanied by a topographic map on the scale of 1 to 625,000.

The coal of the lower Matanuska Valley was studied by G. C. Martin in a reconnaissance made in August, 1905. Martin's report[2] includes a brief account of the geology and geography of the area covered by his work and a more extensive description of the coal, including detailed measurements of many coal beds and analyses of representative samples.

---

[1] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 265–340.

[2] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906.

This region was visited again in 1906 by a Geological Survey party which mapped, topographically and geologically, on the reconnaissance scale (1 to 250,000), the entire Matanuska and Talkeetna valleys, as well as part of the mountains bordering the western edge of the Copper River basin north of the Matanuska Valley. This expedition, which was in charge of T. G. Gerdine, topographer, was accompanied by R. H. Sargent, topographer, and by Sidney Paige and Adolph Knopf, whose report[1] on the geology described for the first time an approximately complete section of the Mesozoic and Tertiary rocks and was accompanied by a geologic map showing the areal distribution of the larger geologic units.

DETAILED SURVEYS.

The detailed topographic map (Pl. IV, in pocket), which was used as the base for the subsequent geologic surveys, was made by R. H. Sargent in 1909.

The detailed geologic investigations which are the chief basis of the discussion presented in the following pages were made in the summer of 1910 by G. C. Martin, geologist; F. J. Katz, assistant geologist; and Theodore Chapin, geologic field assistant. The party also included a cook and two packers. The field season extended from June 3 to September 11.

GENERAL DESCRIPTION OF THE DISTRICT.

GEOGRAPHY.

Matanuska River is tributary to Knik Arm, at the head of Cook Inlet. It rises on the western edge of the Copper River basin and flows between the Talkeetna Mountains on the north and the Chugach Mountains on the south. The Matanuska is about 80 miles in length and has a drainage basin of about 1,000 square miles. Its fall in the part of its course included in the area here described in detail is about 20 feet to the mile. This rapid fall gives it a swift current, because of which and of its being overloaded with sediment and consequently being in most places broken up into many shifting channels over an aggrading flood plain, it is not navigable. The fall is, however, so evenly distributed that there is no available water power.

The principal tributaries of the Matanuska are Caribou Creek, Hicks Creek, Chickaloon River, and Kings River, of which the last two enter it within the area here described in detail. The other

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907.

A. TALKEETNA MOUNTAINS FROM THE WEST SIDE OF KINGS RIVER.

B. NORTH WALL OF MATANUSKA VALLEY ABOUT 12 MILES ABOVE CHICKALOON RIVER.

tributaries which it receives in this area are Coal, Carbon, Granite, Eska, and Moose creeks. It is a noteworthy fact that the larger tributaries of the Matanuska all enter it from the north.

The Matanuska drainage basin may be divided into the mountain areas and the valley areas. The mountain areas include part of the Chugach Mountains south of the river and the Talkeetna Mountains north of it. (See Pl. II, *A*.) The latter are divided by the valley of Chickaloon River into two topographically dissimilar parts which will be shown below to be geologically unlike. The mountains west of Chickaloon River are in general higher and more rugged than those to the east. The height of the summits is in general from 6,000 to 8,000 feet west of Chickaloon River and from 5,000 to 7,000 feet east of it. The general altitude of the summits of that part of the Chugach Mountains which lies in the Matanuska drainage basin is from 7,000 to 8,000 feet.

The Matanuska Valley proper has a general width of about 6 miles between approximately parallel and fairly distinct mountain fronts. Within it are rounded hills and gravel-covered flats, the former rising to elevations ranging between about 2,300 and 3,500 feet and the latter to about 1,200 feet, although small gravel-covered benches are present at the mouths of some of the tributary valleys at elevations as great as 2,200 feet. The streams occupy narrow valleys within this broader valley and some of these are box canyons. It is noteworthy that the Matanuska practically throughout its course is nearer the south than the north wall of the valley, in most places hugging the south wall.

At Moose Creek the valley opens out into the Cook Inlet flats, a gravel-covered lowland in which the irregular hills and ridges rise to elevations in few places exceeding 200 or 300 feet. Between these hills are many marshy flats.

CLIMATE.

The Matanuska Valley, lying as it does back from the ocean, has a climate more like that of the interior of Alaska than that of the coast. The summer temperatures are rather mild; the winters are severe. The precipitation is light, especially in the summer, when, although cloudy days are not infrequent, there is sometimes only a few inches of rainfall during the whole summer. The snowfall is said to be moderate, a total of 3 or 4 feet usually accumulating annually.

The following table is a summary of observations kindly furnished by Mr. Frank Watson and published by Alfred H. Brooks.[1]

---

[1] Brooks, A. H., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 196–198.

Summary of meteorological observations at Chickaloon.

Date.	Temperature (°F.).						Days with precipitation.	Clear days.
	6 a. m.			Noon.				
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.		
1907.								
October 25-31	36	10	27	42	17	32	3 (snow)	1
November	34	− 3	15	40	3	15	4 (snow and rain)	12
December	36	−30	8	32	−28	10	3 (snow)	18
1908.								
January	29	−26	8	30	−15	15	8 (snow)	12
February	32	−21	10	46	− 6	36	5 (snow and rain)	14
March	30	− 3	13	43	10	32	7 (snow)	15
April	42	8	29	52	36	44	4 (snow)	20
May	50	32	42	64	46	55	3 (rain)	14
June 1-25	62	44	52	78	50	61	0	12

Monthly snowfall at Chickaloon.

	Inches.
October, 1907	9¾
November, 1907	13¾
December, 1907	9¼
January, 1908	23¾
February, 1908	8¾
March, 1908	30
April, 1908	4¼
	99¾

March 23, 1908, 3 feet 4 inches of snow on the level; April 14, 1908, 2 feet 6 inches of snow on the level.

The United States Weather Bureau has courteously supplied the observations made by H. H. Hicks at Chickaloon during the period from March, 1910, to March, 1911. They are summarized in the following table:

Summary of meteorological record at Chickaloon, Alaska, March, 1910–March, 1911.

Months.	Temperature (°F.).					Total precipitation (inches).	Snow (inches).			Days with 0.01 inch or more precipitation.	Clear days.	Partly cloudy days.	Cloudy days.
	Mean maximum.	Mean minimum.	Mean.	Maximum.	Minimum.		Total fall.	On ground on 15th of month.	On ground at end of month.				
1910.													
March	32.3	20.3	26.3	50	−12	0.08	7	38	32	2	17	6	8
April	40.1	15.2	27.7	54	− 8	.20		30	12	2	15	9	6
May	58.2	31.6	44.9	78	24	.12				2	11	11	9
June	62.2	39.1	50.7	71	26	1.19				7	6	8	16
July	69.1	45.2	57.2	84	38	1.42				10	11	7	13
August	67.1	40.2	53.7	79	30	.49				4	13	10	8
September	59.4	34.4	46.9	84	21	1.46				8	11	9	10
October	38.7	20.9	29.8	55	− 7	.71	5		3	3	8	10	13
November	22.8	6.6	14.7	34	− 5	.27	6.5	4	6	3	17	4	9
December	15.5	0	7.8	34	−25	.51	9	9	11	3	16	4	11
1911.													
January	12.3	−5.2	3.6	29	−33	.84	13	12	19	4	18	4	9
February	24.2	3.1	13.7	42	−28	2.47	24	22	24	9	9	5	14
March	26.4	1.7	14.1	43	−27	1.15	18	34	30	6	16	4	11

VEGETATION.

Timber line in this area is at a general elevation of 2,000 to 2,500 feet, above which there is the customary growth of small bushes, moss, and grass. The trees include spruce, birch, and several kinds of cottonwood. The growth is in general not dense. Most of the spruce trees are under 12 inches in diameter, the largest one which the writers noted having a circumference of 5 feet. The timber is probably sufficient for any local demands that can now be foreseen, provided that forest fires, which the dry climate favors, are kept under control. There is no timber suitable for export.

The more open birch forests, as well as the areas which have lately been burned, are covered with a dense growth of grass. These natural meadows are large enough to furnish feed for whatever stock is likely to be locally needed.

ACCESSIBILITY.

The Matanuska Valley is at present reached from Knik, which is the head of navigation on Cook Inlet and to which vessels of shallow draft can go at high tide. Near the lower end of Knik Arm there is a good anchorage, which ocean-going vessels can reach at any stage of the tide except during the winter, when the whole upper part of Cook Inlet is frozen.

There is a good horse trail from Knik to the upper end of Matanuska Valley, and the character of the ground and of the vegetation is such that this trail could be made into a wagon road at comparatively slight expense. It takes horses from one to two days to reach Moose Creek, depending on the load, and from a day to a day and a half to go from Moose Creek to Chickaloon River.

At present freight can not be taken in while Cook Inlet is frozen, which is usually from October 15 to May 15, and passengers can reach the region during the winter only by going in from Seward with sleds.

The Alaska Northern Railroad, which is now completed from Seward to Kern Creek, on the north shore of Turnagain Arm, a distance of 72 miles, is intended to reach Matanuska Valley, to which surveys have been made; some construction work has been done between Kern Creek and Knik Arm. According to the present surveys it will be about 150 miles from Seward to Chickaloon River. When this road is completed the Matanuska Valley will be easily accessible at any time of the year.

COMMERCIAL DEVELOPMENT.

The present interest in this region lies chiefly in the coal fields. One of the purposes of the railroad was the development of these coal fields and until they are developed there will probably not be sufficient freight to justify the completion of the road.

The only present inhabitants of the Matanuska Valley are men who are interested in the coal. The town of Knik, although dependent partly for its support on the prospectors in the coal fields, is also the local shipping and supply point for the gold fields on Willow Creek. The latter are at present the chief support of the town.

OUTLINE OF THE GEOLOGY OF THE MATANUSKA VALLEY.

GENERAL FEATURES.

The Matanuska drainage basin and the region immediately contiguous to it may be divided into three mountainous and three lowland provinces. The major areal division is that by Matanuska River, into the Chugach Mountains south of the river and the Talkeetna Mountains north of it. The Talkeetna Mountains are divided by the valley of Chickaloon River into two physiographically and geologically dissimilar parts. The three lowland provinces are (1) the valley of the Matanuska from its source to the point where it emerges from between the Chugach and Talkeetna mountains, (2) the lower Matanuska and Knik Arm flats, and (3) the Copper River Plateau, on the western margin of which Matanuska River has its source.

West of Chickaloon River the Talkeetna Mountains are probably composed chiefly of granite, although metamorphic rocks are known to be present. East of the Chickaloon the Talkeetna Mountains are made up of Jurassic sediments, overlain in parts of the area by late Tertiary volcanic rocks. The geology of that part of the Chugach Mountains which lies within this region is practically unknown, but the rocks are probably chiefly crystalline and largely metamorphic.

The less mountainous area adjacent to Matanuska River contains mainly Tertiary and Mesozoic sediments. The area described in detail in this report lies chiefly within this province.

The Knik Arm flats and the Copper River plateau are covered with Quaternary gravels and the nature of the underlying rocks is unknown.

The accompanying geologic map (Pl. III, in pocket) shows the areal distribution of the rocks throughout the Matanuska Valley. The general stratigraphic sequence is given in the following table:

Stratigraphic sequence in the Matanuska Valley.

Age.		Lithologic character.	Thickness (feet).
Quaternary.		Alluvium. Terrace gravels. Morainic deposits.	
Tertiary.	Pliocene (?).	Basaltic lavas, breccias, and tuffs	800+
	Miocene (?).	Eska conglomerate	2,500
	Eocene.	Chickaloon formation;[a] shale and sandstone, coal bearing Arkose, conglomerate, and shale	2,000± 2,000±
Upper Cretaceous.		Shale and sandstone	4,500±
Lower Cretaceous.		Limestone	300+
Upper Jurassic.		Shale, sandstone, and conglomerate	2,000±
Middle Jurassic.		Sandstone and shale	1,000±
Lower Jurassic.		Andesitic greenstone, tuffs, agglomerates, and breccias; rhyolites, dacites, and tuffs	1,000+
Early Mesozoic or older.		Graywackes, slates, basaltic greenstones, and rhyolites and tuffs	(?)
Paleosoic.		Mica schists and other schistose and gneissic rocks	(?)

[a] Carries Kenai flora.

MICA SCHISTS.

Mica schists form a narrow belt, not over 3 miles wide, near the head of Willow Creek. This belt has an east-west direction, is not known to extend farther east than Little Susitna River, and disappears westward beneath the gravel floor of Susitna Valley.

These schists include garnetiferous mica schists and chlorite-albite schists. They are thoroughly foliated rocks of medium grain and show in general no variations in appearance.

The strike of the schistosity varies from N. 45° E. to N. 60° W. The dips average near 40° but are inclined on both sides of the vertical. Fossils have not been obtained in these rocks, nor is their occurrence likely. On account of the thorough metamorphism it has undergone, which considerably exceeds that of any of the rocks presently to be described, this formation is regarded as representing the oldest rocks of the region. Its members show a petrographic similarity to the mica schists of the Yukon-Tanana region, and a possible correlation with the pre-Ordovician of that region is suggested.

GRAYWACKES AND SLATES OF THE KNIK RIVER REGION.[1]

The rocks on the south side of Knik Arm and in the valley of Knik River consist largely of graywackes, slates, and phyllites, with some greenstones, rhyolites, and tuffs. The general strike of the series (N. 60° E.) tends to carry them eastward approximately parallel to the course of Matanuska River. Their occurrence farther east is indicated by the fact that the moraine of the great glacier at the head of Knik Valley is composed exclusively of graywacke and slate.

The graywackes are highly indurated rocks, whose most conspicuous feature to the unaided eye is the unusual abundance of small angular slate fragments. They are dark bluish gray and at some places are not easily distinguishable from basic volcanic rocks. The graywackes are roughly schistose and pass by increasing fineness of grain into graywacke slates and highly cleaved clay slates. Locally the slates assume a schistose foliation, become glossy, and pass into phyllites. At Knik Glacier they are affected by slip-strain cleavage and are acutely crumpled and contorted. The interbedded graywacke, however, has been rendered only roughly schistose. Quartz stringers are very abundant in the slates and graywackes and at places form an intricate network of small veins, averaging about an inch in thickness. Mineralization of the quartz is not visible to the eye.

Near the mouth of Knik River a great volume of greenstone tuffs, estimated as probably 1,500 feet thick, was found associated with the graywackes. They are dense, fine-grained rocks of green color, conspicuous on account of the numerous angular fragments of black slate which they inclose.

The massive greenstones are, as a rule, nonporphyritic rocks of aphanitic texture. The original structure is in places obscured by abundant developments of secondary minerals, such as light-green hornblende, chlorite, and epidote, but remnants of ophitic or closely allied textures are sufficiently well preserved to leave no doubt as to the original character of the rock.

Rhyolites and their tuffs are associated with slates at a locality halfway up Knik River. The acidic volcanic rocks are of felsitic habit and include flow-banded types and porphyritic phases with inconspicuous quartz phenocrysts. A rude schistosity has been impressed on them.

The tuffs accompanying the rhyolites, like the greenstone tuffs, are remarkable for the abundance of small, angular slate fragments which they include. Microscopic study indicates that the rhyolite tuffs grade into graywackes. A transitional type is represented by a rock in which glassy quartzes and white feldspars are studded in porphyritic fashion in a dense greenish matrix.

---

[1] These rocks have not been studied by the authors of this report, and the description here given is an abstract of that by Paige and Knopf (Bull. U. S. Geol. Survey No. 327, 1907, pp. 12-16).

The general petrography of the rocks of the Knik region proves that the graywackes were derived largely from the destruction of a granitic rock, probably, as the inclusions in the greenstone tuff show, of quartz diorite character.

The various rock types—graywackes, greenstone tuffs, and rhyolite tuffs—are characterized by the presence of numerous small, angular slate fragments. Metamorphism has not proceeded far enough to mask the clastic origin of the typical members, nor to cause a marked development of new minerals.

The cleavage of these rocks is parallel to the bedding. The strike, which is N. 60° E. at the mouth of Knik River, gradually swings around to the north as the Knik is ascended and becomes N. 10° E. at Knik Glacier. This change of strike in the strata coincides in a general way with the change in the axial trend of the Chugach Mountains, which in this region make a great bend to the south and continue into Kenai Peninsula as the Kenai Mountains. The dips are usually high, ranging from 40° to 90°. Structurally the series presents a monoclinal succession of steeply dipping strata, which is undoubtedly due to repetition by close folding.

No fossils have yet been found in these rocks, so that only tentative conclusions regarding their age can be drawn. The slates and graywackes of the region under discussion are more highly metamorphosed than the shales and sandstones in the adjoining Matanuska region. As the latter are shown by their marine fauna to be in part Lower Jurassic, an age probably earlier than that is indicated for the slates and graywackes. From a similar line of evidence in the Kachemak Bay region Moffit[1] has regarded the Sunrise "series" of Kenai Peninsula, with which these rocks are probably to be correlated, as of pre-Jurassic and probably Paleozoic age.

LOWER JURASSIC ROCKS.

The oldest rocks of this region of which the age has been definitely determined are Lower Jurassic volcanic beds. These occur in small areas within the area shown on the detailed geologic map (Pl. V, in pocket), and such occurrences are described fully below. They also cover large areas near the headwaters of Matanuska and Chickaloon rivers, where they were studied by Paige and Knopf,[2] who referred them to the lower Middle Jurassic. The following paragraphs are abstracted from their description of these rocks:

The Lower Jurassic rocks comprise andesitic greenstones, quartz porphyries, and tuffaceous sandstones. The greenstones constitute the most characteristic member and attain a wide distribution, especially in the interior of the Talkeetna Mountains.

---

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, p. 19.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 16-17.

The great bulk of the greenstones is largely in the form of stratified breccias in which angular fragments of dark-blue porphyritic rock, varying in size from pieces of microscopic dimensions to blocks several feet in diameter, are inclosed in a matrix of green color. This contrast of colors, which serves to emphasize the breccia character of the rock, is due to the fact that the matrix is abundantly changed into the green mineral chlorite, whereas the large angular fragments, being of a dense, fine-grained texture, have in places withstood alteration more thoroughly. With the breccias are intercalated sheets of amygdaloids, porphyries, and flow breccias. In many places the amygdaloids are studded with numerous large amygdules of chalcedony, quartz, calcite, chlorite, or zeolite.

A prominent feature of the greenstones is the great amount of shattering and slickensiding which they exhibit. Where this internal movement has been of a more regular character a rude schistosity has been impressed on them. Extensive pyritization of a diffused character was noted at several localities, but a thin irregular seaming with calcite appears to be the most usual form of mineralization.

Petrographically the greenstones are prevailingly andesitic and more or less completely chloritized. Examples more basic than andesite appear to be rare and were noted only on Boulder Creek about 7 miles from its mouth, where greenstones displaying columnar structure make up the north wall of the valley. These prove to be diabase porphyries.

Here and there the thickness of the greenstones exceeds 1,000 feet. The tuffs locally contain fragments of lignite, and at the east end of Sheep Mountain, in the upper Matanuska Valley, they carry marine shells in a fine state of preservation.

Various rhyolites and dacites, including their tuffs, are associated with the greenstones. These rocks are widely distributed in the interior of the Talkeetna Mountains. The rhyolites are generally flinty looking rocks containing glassy phenocrysts, but also include some distinctly flow-banded phases. Devitrification is common in the rhyolites. Some of the dacites resemble the rhyolites in appearance, but others possess a greenstone habit. These acidic lavas appear to have been erupted either during or soon after the period of the andesitic extrusions, as they contain included fragments of microlitic andesite.

During the extravasation of the rhyolites conditions were not uniform over the province. While lavas were accumulating in some portions of the region sedimentation was progressing in others. On the divide between Hicks and Boulder creeks a white stratum 20 feet thick is prominent. It proves to be a feldspathic sandstone, with some irregular thin white bands, about a quarter of an inch thick, scattered through it. The microscope shows that these bands are composed of microspherulitic particles and fragments of devitrified rhyolite, with fine flow structure, indicating that showers of rhyolitic material were prevalent during this portion of the Lower Jurassic epoch.

GRANITIC ROCKS.

Granitic rocks of granite, quartz diorite, and quartz monzonite habit and for the most part of moderately coarse granitoid texture, though locally foliated, occupy most of the mountain province north of Matanuska River and west of Chickaloon River. These rocks are thus geographically restricted save for a small mass on Sheep Mountain which has been regarded by Paige and Knopf[1] as equivalent to the granitic rocks here discussed. Much of the rugged interior of the Talkeetna Mountains remains unexplored, but such evidence as is available indicates that the great central area consists largely of granitic rocks. The morainal material brought down by the glaciers from the remote recesses of the range and the gravels of the streams heading in the mountainous interior consist prevailingly of granitic material.

A considerable variety of rock types is found, but quartz diorites appear to predominate. A quartz diorite north of Moose Creek carries the dark minerals hornblende and biotite and is associated with a quartz diorite gneiss rich in hornblende. This gneiss extends also eastward to and along Granite Creek and is doubtless a cataclastic phase of the massive quartz diorite. Along the middle course of Chickaloon River quartz-augite diorite is present, but toward the headwaters it gives place to a muscovite granite. On the upper Talkeetna gneisses again appear, but along the lower course are exposed more quartz diorites. On the western flank of the Talkeetna Mountains granitic rocks outcrop in great abundance almost continuously from Talkeetna River to Willow Creek and again as a narrow band forming the southern boundary of the area of crystalline mica schist. Near Sheep Creek some uralitic gabbro is found. In the vicinity of Kashwitna River is a light-colored quartzose type, which proves to be a quartz monzonite.

The quartz diorites on the south side of Knik Arm are probably to be correlated with those making up the main mass of the Talkeetna Mountains. Similarly a small isolated boss of epidotized quartz diorite a few miles east of the mouth of Caribou Creek appears to belong to the same general mass.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 20.

MIDDLE AND UPPER JURASSIC ROCKS.

The Middle and Upper Jurassic rocks of the Matanuska Valley were not recognized within the area here described in detail, but they have a considerable thickness and wide distribution farther east. They contain faunas which seem to represent those of all the Middle and Upper Jurassic formations present on Cook Inlet, although the beds containing the several faunas have not been separated in areal mapping. The following description of these beds is compiled from the report by Paige and Knopf.[1]

In the region east of Chickaloon River the Lower Jurassic volcanic rocks (lower Middle Jurassic of the report cited above) are overlain with apparent conformity by a series of sandstones and shales. Some finely flow-banded volcanic rocks, now devitrified, are in places associated with the sediments, proving that eruptive activity had not entirely ceased during their deposition. This series, by its dominantly sedimentary character, can be readily distinguished from the underlying meta-andesite.

The sandstones are usually feldspathic and under the microscope show numerous small fragments of microlitic andesite no larger than the feldspar or quartz grains. The shales locally carry numerous limestone nodules. At several localities these shales and sandstones are intensely shattered and crushed. This is especially notable in the gorge of Billy Creek. In this vicinity also occur several conglomerates not found elsewhere in the series.

In general the sandstones and shales are barren of fossils, though belemnites are rather common. The following species, however, were found and were submitted to T. W. Stanton, who reported as follows:[2]

6 A. K. 88A. Caribou Creek, tributary to Matanuska River:
 Inoceramus cf. lucifer Eichwald.
 Pleuromya.
 Pleurotomaria.
 Phylloceras.
 Stephanoceras.
 Oppelia?
6 A. K. 88B. Same locality as preceding, but found in float bowlder in stream bed:
 Inoceramus.
 Natica.
 Phylloceras.
 Stephanoceras.
 Sonninia? (two species).
 Belemnites.

The two lots are evidently from the same horizon and nearly all the species occur in the lower part[3] of the Enochkin at Snug Harbor.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 17-23.

[2] Idem, p. 19.

[3] The lower part of the Enochkin formation is now known as the Tuxedni sandstone. (See Bull. U. S. Geol. Survey No. 485, 1912, pp. 59-64.)

The Upper Jurassic rocks consist largely of blue shales, locally carrying fossiliferous limestone nodules. With the shales are associated sandstones, conglomerates, and some tuffs and arkoses. Strata of this age have a wide distribution east of Chickaloon River, but were not observed in the Talkeetna Mountains.

The sandstones of this series are usually ordinary yellow sandstones, which in places are conspicuous on account of the multitudes of Aucella contained in them, this fossil making up as much as half of the rock. In some places the sandstones have a light-gray color, due to the fact that such beds are highly feldspathic and contain much finely comminuted black mica, locally with an abundance of small bits of carbonaceous material.

On Billy Creek a number of interstratified tuff beds from 1 to 4 feet thick occur near the top of the series, a few hundred feet beneath the base of the Cretaceous. These tuffs differ greatly in appearance from the older Jurassic tuffs. Higher in the series arkoses closely simulating granites in appearance are interstratified with the sandstones. The arkose appears to have been derived principally from the destruction of a volcanic land mass, but some of its material was possibly brought from a monzonite area, as indicated by the presence in it of fragments of monzonite. Under the microscope the feldspars of these arkoses by their alteration contrast strongly with the clear, glassy feldspars of the somewhat older crystal tuffs already described.

A notable accumulation of conglomerate, stretching over several square miles, occurs in the headwater region of Susitna River near Nelchina River, where extensive glaciation has produced deep troughs that expose splendid sections of it. Perpendicular cirque walls reveal a thickness of not less than 1,100 feet. Here and there thin layers of sandstone show that the conglomerate is lying in horizontal attitude. It is almost exclusively composed of large, well-rounded bowlders of augite andesite and quartz monzonite embedded in a tuffaceous matrix. At the upper horizons the bowlders of andesite preponderate. The bowlders of the conglomerate are ellipsoidal in shape, and many of them are as much as 2 feet in diameter. The conglomerate is lithified firmly enough to form large bowlders in the present stream wash. Sheets of lava are locally intercalated in the conglomerate.

Along Nelchina River, immediately below the junction of the north and south forks, the stream bluffs reveal an interdigitation of lenses of sandstone, shale, and coarse conglomerate. The sandstones show cross-bedding and contain remains of Aucella.

The thickness of the Middle and Upper Jurassic rocks is not definitely known. It certainly exceeds 2,000 feet, including a known thickness of 1,100 feet of conglomerate.

The unconformity between the Upper and the Lower Jurassic records an important event in the dynamic history of the area. Below this break in stratigraphic sequence the rocks are shattered and broken and in many places are rudely schistose, and the andesites have assumed a greenstone habit and in several places have been extensively pyritized and veined by quartz and calcite seams. Above the unconformity the strata lie in comparatively undisturbed attitudes and the intercalated andesites are fairly fresh and unaltered, differing in this respect but slightly from the Tertiary volcanic rocks of the region.

The age of these strata has been determined from the following invertebrates, identified by T. W. Stanton:

Lot 6 A. K. 156. Headwaters of Nelchina River of Copper River drainage:
Cadoceras sp. Many immature specimens.
Belemnites. Fragments.

The horizon is that of the Cadoceras zone,[1] which forms the upper third of the Enochkin formation.

Lot 6 A. K. 185. Nelchina River:
Pleuromya.
Cadoceras? Fragmentary imprint doubtfully referred to the genus.
Belemnites.

The horizon is probably in the upper part[1] of the Enochkin formation.

Lot 6 A. K. 136. Billy Creek:
Aucella cf. bronni Rouiller.

The same species occurs in similar rock in the Naknek formation of Kamishak Bay.

The fossils indicate faunas of both late Middle Jurassic and Upper Jurassic age. It is interesting to note that the Upper Jurassic rocks of this region, which are faunally allied to those of the Naknek formation on the west coast of Cook Inlet, show a certain lithologic similarity in the presence of interstratified tuffs and arkose.[2] Furthermore, an accumulation very similar to the remarkable andesite-granite conglomerate occurring on the headwaters of Susitna River is found at the base of the Naknek formation.[3]

LOWER CRETACEOUS ROCKS.

The Lower Cretaceous is represented by a single formation—a massively bedded limestone, 300 feet thick, which overlies the Upper Jurassic strata conformably on the headwaters of Billy Creek and Nelchina River, where it outcrops in prominent gray cliffs encircling the hilltops. It is also represented by the probably equivalent limestone north of Castle Mountain described below (pp. 32–33). The limestone at the headwaters of Billy Creek and Nelchina River is described by Paige and Knopf[1] as white and of very finely saccharoidal texture. On fresh fracture it emits a strong fetid odor. It is readily soluble in cold hydrochloric acid and evolves an abundance of unpleasant hydrocarbon gases. Qualitative tests show the presence of not more than a trace of magnesia. Under the microscope the detrital organic origin of this limestone is readily apparent. It is composed largely of irregular granules of dirty-looking calcite, but with these are associated numerous prismatic sections referable to organic fragments. Rhombohedral cleavage is here and there finely developed, but the characteristic calcite twinning is notably absent. Some of the carbonate is still in the aragonite form, as is indicated by negative biaxial interference figures. Accessory constituents are limpid plagioclase, quartz with hairlike rutile, hornblende, and, more rarely, augite and apatite. The incomplete conversion of the carbonate to the stable modification and the absence of twin lamellation in the calcite indicate the essentially static conditions in which the limestone has remained since its formation.

---

[1] The Cadoceras zone, constituting the upper part of the Enochkin formation, is now known as the Chinitna shale. (See Bull. U. S. Geol. Survey No. 485, 1912, pp. 65–68.)

[2] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet: Bull. Geol. Soc. America, vol. 16, 1905, p. 402.

[3] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: Bull. U. S. Geol. Survey No. 250, 1905, p. 44.

The age determination of this Cretaceous formation is based on the presence of *Aucella crassicollis* Keyserling, obtained by Mendenhall[2] from a conglomeratic sandstone at the base of the limestone. This conglomerate may indicate a time break between the Lower Cretaceous rocks and the Upper Jurassic strata that lie in apparently conformable attitude beneath them.

UPPER CRETACEOUS ROCKS.

The Upper Cretaceous rocks of the Matanuska Valley consist of about 4,500 feet of shale and sandstone, deposited, so far as known, wholly in marine waters. These deposits have been recognized in this part of Alaska only within the area described below in detail. The character and age of these beds were not recognized in the earlier investigations, and they are included in the areas mapped as Tertiary by Martin[3] and by Paige and Knopf.[4] It is highly probable that they extend east of the area shown on the detailed map (Pl. V, in pocket) and include beds represented on the general geologic map (Pl. III, in pocket) as Tertiary or as Upper and Middle Jurassic.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 24.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 309.

[3] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, Pl. III.

[4] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, Pl. II.

TERTIARY ROCKS.

The Tertiary sedimentary rocks of the Matanuska Valley have in the earlier descriptions been treated as a stratigraphic unit and are thus represented on the general geologic map (Pl. III, in pocket). It has been found possible and desirable, in the area mapped in detail, to subdivide these rocks. Three Tertiary formations are consequently represented on the detailed geologic map (Pl. V, in pocket) and will be described below. These formations are, in descending order, the Eska conglomerate, the Chickaloon formation, and an unnamed formation consisting of arkose, conglomerate, and shale. The local Tertiary rocks include also volcanic beds and intrusive masses.

The subdivisions of the Tertiary have been carried only over the area of the detailed geologic map (Pl. V), so it is necessary to map the Tertiary as a unit in the remainder of the valley. (See Pl. III.) The Tertiary rocks along Chickaloon River north of the end of Castle Mountain are chiefly conglomerate and are believed to include both the Eska conglomerate and the conglomerates of the basal Tertiary formation. The area mapped as Tertiary east of Chickaloon River is probably occupied chiefly by the Chickaloon formation.

Overlying the older Tertiary rocks unconformably is a series of nearly horizontal basalt flows, which, with their intercalated pyroclastic rocks, attain a thickness of 1,000 feet. They were seen within the area mapped in detail only on Castle Mountain, but they are extensively distributed throughout the Talkeetna Mountains and compose many of the peaks and summits of the region. They weather in tints of red and break down in characteristic erosional forms which lend a picturesque castellated appearance to the mountain crest lines.

The basalt flows with their interbedded tuffs and breccias present a stratified appearance. The surface upon which these volcanic rocks were accumulated appears to have been one of gentle relief, cut across the upturned edges of the older rocks. The discordance between the nearly horizontal basalts and the underlying strata varies from 10° to 90°. About the headwaters of Chickaloon River this basalt surface slopes gently northward. East of Chickaloon River its altitude is about 5,000 feet. It is somewhat broken by faults.

The basalts display a wide variation in habit and texture. Highly glassy types, amygdaloids, porphyries, and dolerites are variously represented. They belong to the acidic end of the basalt family and are in general nonolivinitic.

The basalts overlie the Eska conglomerate unconformably and are probably of late Tertiary and possibly of Pliocene age. Their petrography suggests that they are the effusive equivalents of the diabase dikes and sills that are so common in the Tertiary of the Matanuska Valley. These volcanic rocks of the Talkeetna Mountains can be correlated with the great Tertiary volcanic series of the upper Nizina Valley, described by Schrader and Spencer, and with an important volcanic series on Nabesna River, described by Brooks. Both these series are said to comprise andesites, rhyolites, and pyroclastic rocks and both were deposited unconformably upon a general uniform surface. The volcanic rocks of the Talkeetna region, however, show a greater petrographic uniformity and consist exclusively of basalts and their fragmental accumulations. In this respect they show a closer resemblance to the late Tertiary lavas of the Alaska Peninsula, and the Aleutian Islands, which have been described by Spurr[1] as andesitic basalts.

QUATERNARY DEPOSITS.

The Quaternary deposits include morainic accumulations, terrace gravels, and the alluvial deposits on the present flood plains. The glacial deposits and terrace gravels are especially well developed throughout the lower lands west of Chickaloon River, where the former glaciers and the glacial streams were depositing. Farther east, where the glaciers were eroding more actively and where they stood above the level of the waters in which the terraces were formed, the gravel cover is thin and local.

The deposits in the valley of the Matanuska are described in detail in the following pages. The Quaternary deposits on the lowlands bordering Knik Arm are of somewhat different character.

The bluffs on the shore of Knik Arm in the vicinity of Knik are composed entirely of Quaternary deposits. Those at Knik are made up of stratified sand and gravel, but an exposure seen from the steamer several miles below (near or just above Goose Bay) is apparently unstratified and is probably till.

The bluffs from Knik to Cottonwood are all of stratified sand and gravel, as at Knik. They rise to a general elevation of about 100 feet above high tide. The upper limit is a well-defined level behind which the surface is hummocky. At Cottonwood the general upper surface level is well developed at 57 feet above extreme high tide, there being also a distinct bench at 16 feet. Exposures of the material are poor, but the good drainage and the presence of only well-washed material in the slides indicates that the gravel is stratified and not a strict morainic deposit.

The trail from Cottonwood to Grassy Ridge passes through a hummocky but fairly well terraced country whose surface gradually rises toward Grassy Ridge. The topographic forms appear to include a variety of features of glacial origin, such as eskers, possibly drumlins, and irregular glacial dumps, as well as benches which may be products purely of glacial outwash but which, presumably, include also marine terraces (chiefly constructional). The rise toward Grassy Ridge is accomplished chiefly by steep ascents from bench to bench. Grassy Ridge is a long, narrow, steep-sided, sinuous gravel ridge on the north shore of Finger Lake. North of it is a creek flowing westward. The crest of the ridge undulates in elevation, the average height being about 36 feet above Finger Lake and 47 feet above the creek.[1] The ridge is probably an esker, though possibly a piece of lateral moraine. The trail traverses other similar ridges west of this point.

---

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 234.

The trail from Grassy Ridge to Moose Creek passes over a country similar to that from Cottonwood to Grassy Ridge until it crosses the second creek, beyond which it rises by a gentle slope toward the bank of Matanuska River. It comes out on top of the bank overlooking the Matanuska about 3 miles below Moose Creek, where it is on stratified gravel at an elevation of about 300 or 400 feet above the river. From this point it runs near the edge of the bank, going over flat benches, all of which are apparently at about the same elevation, and in and out of shallow draws and undrained hollows. The trail descends into the valley of Moose Creek over several well-defined benches, which are described more fully below.

DETAILED DESCRIPTION OF THE ROCKS OF THE LOWER MATANUSKA VALLEY.

GRANITIC AND GNEISSIC ROCKS.

AREAL DISTRIBUTION.

Granitic and gneissic rocks occupy two areas along the northern border of the region covered by the detailed map (Pl. V, in pocket). One of these areas extends from the valley of Moose Creek to the headwaters of Young Creek and northward into the Talkeetna Mountains for an unknown distance. It probably includes the entire upper parts of the valleys of Moose and Granite creeks, for the beds of these streams at the edge of the region mapped on Plate V are made up entirely of bowlders of granite, and no sedimentary rocks could be seen in the mountains at their heads. The other area extends from the divide between Young and Granite creeks to the divide between Kings and Chickaloon rivers and up Kings River probably to its headwaters, although sedimentary rocks also are known to be present here.

---

[1] The difference of elevation was measured with a hand level.

LITHOLOGIC CHARACTER.

The older crystalline rocks within the area represented on the detailed map comprise granites and quartz diorites, many of which are more or less gneissoid, and also probably smaller but undifferentiated masses of thoroughly gneissic and fine-grained schistose rocks. The granite rocks are for the most part light colored, moderately coarse grained, and of a granitic texture and contain macroscopic quartz, feldspar, hornblende, and in some places also biotite.

Gneissic banded rocks of moderately fine grain, composed of quartz, feldspar, and hornblende, are present on Moose Creek. Intrusive into these rocks are fine-grained whitish granitic rocks of alaskitic habit, composed of quartz, feldspar, and very little biotite. Coarse-grained, slightly gneissoid granites are also present in this locality. The gneissoid texture of these rocks is due to a rough parallelism of constituent minerals which, under the microscope, are seen to be crushed, granulated, and bent and to have undergone considerable alteration to secondary minerals. These granites of cataclastic gneissoid habit are composed of primary quartz, alkalic feldspars, hornblende, and biotite, and accessory magnetite and apatite. The secondary minerals are chiefly quartz, iron oxides, chlorite, and epidote.

On Eska Creek there are both distinctly banded gneissic rock and merely gneissoid granite, similar to the rocks on Moose Creek. No banded gneissic rocks were seen east of Eska Creek, but most of the granites along the southern borders of their areas are gneissoid.

In the neighborhood of Kings River there are granites of medium grain consisting of quartz, acidic plagioclase (and orthoclase?), biotite, hornblende, and magnetite. There is some variety in these rocks due to reciprocal relations in the amounts of feldspar and ferromagnesian minerals, especially the hornblende. The rocks containing more of the ferromagnesian minerals are usually finer grained and much darker in color. Small patches or "inclusions" of such rock within the lighter, coarser varieties are very common.

Along the fault zone which marks their south boundary the older crystalline rocks are, at several places, as on Eska Creek and on the ridge north of Castle Mountain, severely crushed and altered, with the development of epidote, chlorite, calcite, and other minerals, so that their original characters are very obscure. In some of these deformed rocks there is very profound veining by irregular and small to minute seams of calcite and quartz.

AGE AND RELATIONS.

The granitic rocks and the highly metamorphosed gneissic rocks which occur in association with them constitute a complex which could not be divided in the small amount of investigation which was made on the margin of their area. The gneissic rocks are believed to be part of a possibly extensive ancient series of metamorphic rocks having close relations with the mica schists on Willow Creek. (See p. 15.)

The gneissoid granites, which are very certainly younger than the rocks just mentioned, may be the representatives of a granite mass which was slightly metamorphosed and intruded by later nongneissoid granites. On the other hand, they may very probably be but the locally altered representatives of one general mass, of which the nongneissoid granites are another facies. There is little in favor of either of these alternatives, unless it be in the evidence of two widely separated periods of granitic intrusion, found in the facts that Jurassic rocks are intruded by granites (see below) and that the pre-Jurassic (see p. 17) graywacke on Knik Arm is composed of detritus from the destruction of a granite mass.[1]

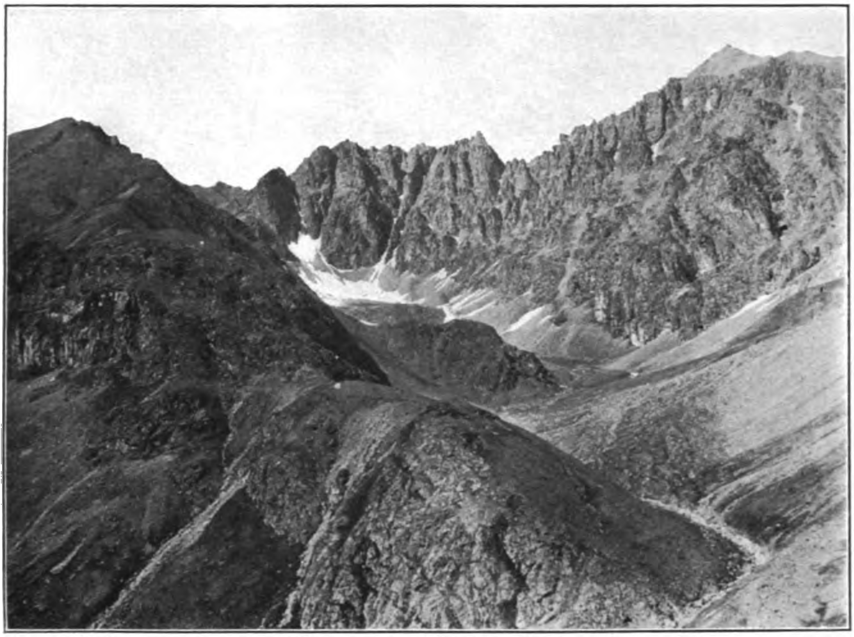
The arkosic rocks, which are believed to be at the local base of the Tertiary, rest upon an even surface of granite, contain pebbles identical in lithologic character with the underlying granite, and are believed to have been laid down upon an eroded granite land surface (See Pl. VI, *A*.) The general southern boundary of the granite areas is in most places along faults by which the granites are brought into contact with both the Tertiary and the Upper Cretaceous rocks. (See Pls. VI, *B*; VII, *A*; and XIV, *A* and *B*, p. 72.) The granite is in contact with the Lower Jurassic volcanic rocks and with the probably Lower Cretaceous limestone in the ridge north of the west end of Castle Mountain. The nature of the contact at this point is not as clear as could be wished. Near the contact the granite shows evidence of having been severely crushed, and there is probably some faulting at this locality. The actual contact could not be observed at close range, so it is not known definitely whether the granite is intrusive into either or both of the Mesozoic formations. The contact, as seen in cliffs which were inaccessible, looked very much as if it were intrusive. On the other hand, the granite is not noticeably finer grained near the contact than away from it, nor could it be seen that the limestone or the Lower Jurassic volcanic rocks were more altered near the edge of the granite mass.

The date of intrusion of the granitic mass of the Talkeetna Mountains is assigned to the Middle Jurassic by Paige and Knopf[2] on the ground that the Upper Jurassic rocks on the headwaters of the Matanuska contain bowlders of granite identical in character with that of the mountains, and the Lower Jurassic volcanic rocks on Sheep Mountain are cut by a small mass of granite. There is a

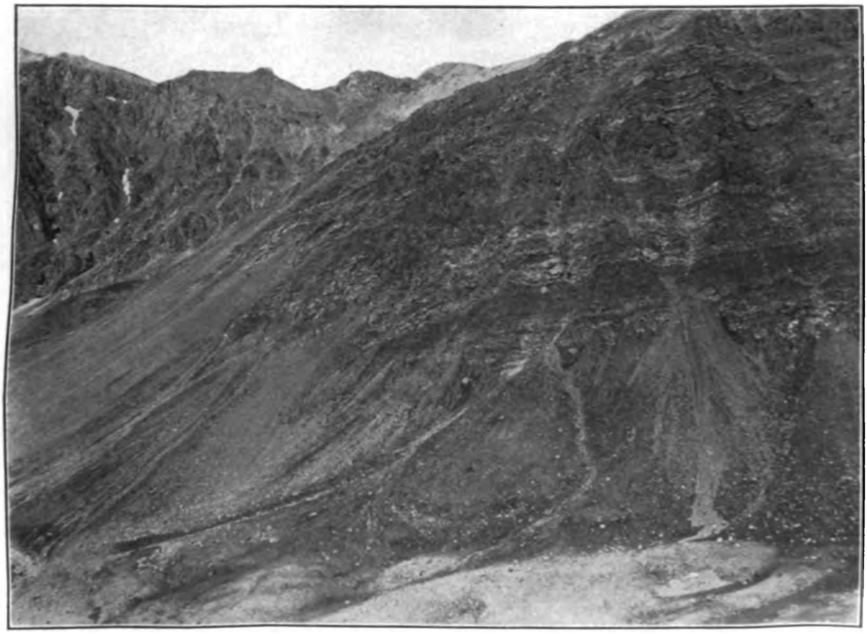
---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 14-15.

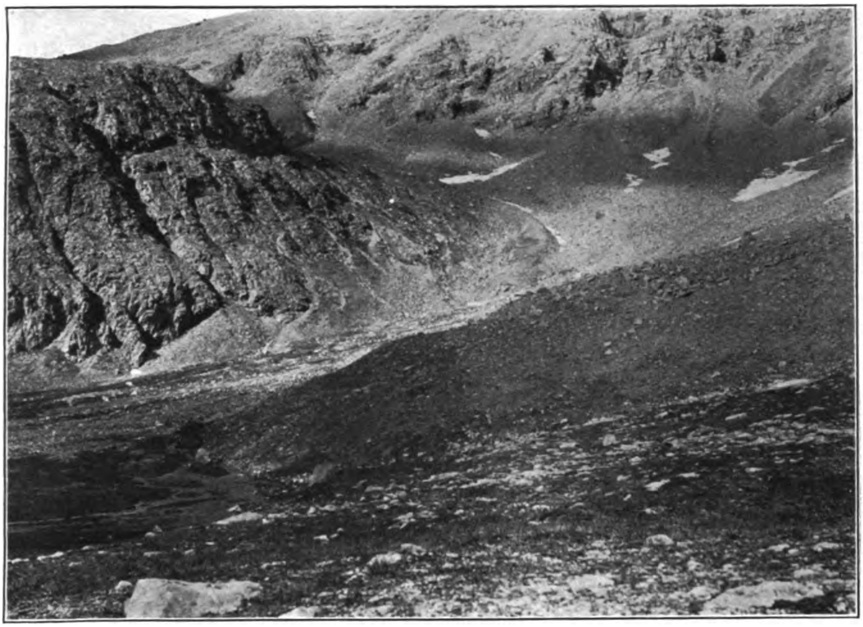
[2] Idem, p. 21.



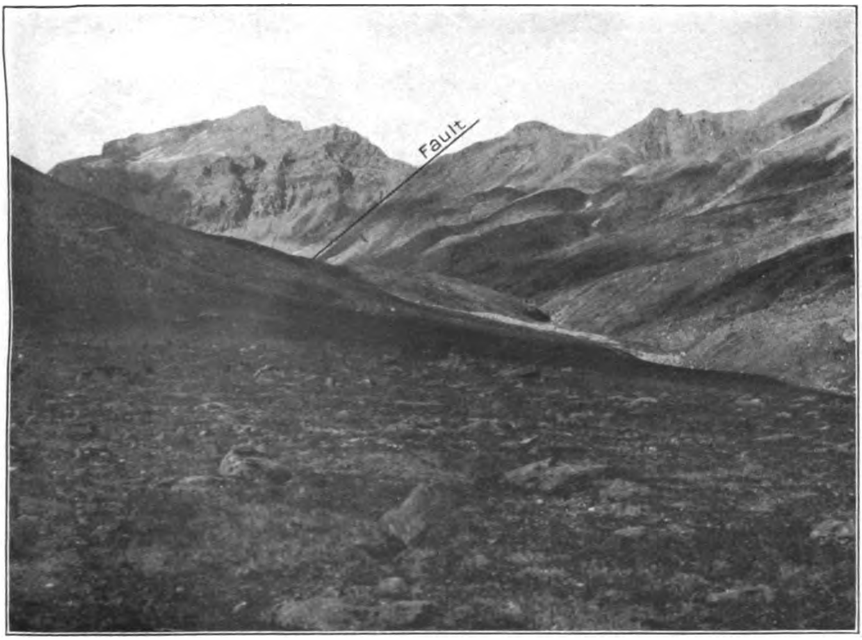
A. GRANITE AND TERTIARY ARKOSE IN GULCH ON THE WEST SIDE OF SHEEP VALLEY.



B. GRANITE AND TERTIARY ARKOSE IN THE WEST WALL OF SHEEP VALLEY.



A. GRANITE OVERLAIN BY ARKOSE AT THE HEAD OF SHEEP VALLEY.



B. SHEEP VALLEY FROM A POINT NEAR ITS LOWER END.

Showing the gently dipping arkose represented in Plate VII, *A*, overthrust on closely folded arkose beds.

weak point in this evidence, as the small granite mass on Sheep Mountain is 28 miles distant from the main granite mass of the Talkeetna Mountains and may or may not be contemporaneous with it. The evidence is, however, very suggestive and is in harmony with the apparently intrusive character of the contact of the granite with the Lower Jurassic volcanic rocks north of Castle Mountain and with what is known of the date of intrusion of similar granite masses not only in Alaska but throughout the American Pacific coastal mountains.

LOWER JURASSIC ROCKS.

VOLCANIC BRECCIA, AGGLOMERATE, AND TUFF.

AREAL DISTRIBUTION.

The Lower Jurassic rocks occupy two areas in the east end of the district here under discussion. They occur in a belt north of Castle Mountain, extending from Kings River to and probably beyond Chickaloon River, and in another belt south of and parallel to the Matanuska, extending from Carbon Creek eastward for an undetermined distance. They also occupy large areas in the upper Matanuska Valley and in the region north of it, as will be noted below.

LITHOLOGIC CHARACTER.

These rocks are well exposed on the creek tributary to Chickaloon River from the west a mile above the Government Bridge. The beds here exposed consist of lavas, agglomerates, and breccias of considerable diversity of character interbedded with tuffs which are waterlaid and well bedded and which carry abundant marine fossils of the species listed below. Beds of the same character were seen on Doone Creek immediately behind the east end of Castle Mountain, where also fossils were obtained.

The exposures seen on the mountain north of the west end of Castle Mountain consist entirely of the more typical volcanic accumulations, without recognized bedded rocks, and reveal more alteration of the rocks than was seen at the exposures first described. The rocks at this point are rather of the greenstone type.

Coal Creek, at a point about 1¾ miles above its mouth, passes through a narrow gorge both walls of which are made up of green tuff with angular inclusions and rolled pebbles of red, purple, and green igneous rocks. These rocks have a structure dipping northward at an angle of 10° or 15°, which may be bedding.

Just below this gorge, on the east bank of the creek, northward-dipping graywacke or fine-grained tuff is exposed in a contact of undetermined relationship with the coarser tuff seen in the gorge. These beds seem to grade upward into shales which are harder than the typical shales of the Tertiary and approach in character the Cretaceous shale on Kings River. Interbedded with the shale is a 4-foot bed of conglomerate of different character from any seen in the Tertiary.

Above the gorge, on the east bank of the creek and well exposed at the north end of the high cliffs shown on the map near the edge of the sheet, are more massive fine-grained rocks, which are believed to be also tuffaceous.

The Mesozoic volcanic rocks north of Doone Creek include a number of lavas, tuffs, and breccias which constitute part of the bedded series of volcanic rocks described by Paige and Knopf[1] and which have a more varied and extensive development outside the limits of the area here described in detail. North of Doone Creek the following rocks were seen: Felsites of creamy white and drab color, the former containing phenocrysts of small white feldspar and black decomposed biotite (?); brownish-green narrow-banded tuffs of fine angular, clastic texture; dark fine-grained fragmental rocks studded with small white feldspar crystals; banded fossiliferous tuffs composed of angular bits of feldspar and hornblende or other dark mineral or fragments of dark rock; stratified breccias in which angular fragments of porphyritic or felsitic rocks are embedded in a matrix of only slightly different appearance, accentuated on weathered surfaces; and black aphanitic vesicular basalts. All these rocks are much weathered. The prevalent green color indicates general development of secondary minerals and decomposition products. Some of these rocks are severely crushed and shattered and in them epidotization and chloritization are particularly pronounced. These rocks are intricately interlaced with small quartz and calcite seams. Paige and Knopf found among these rocks mainly andesites, dacites, and rhyolites and their tuffaceous equivalents.

FAUNA.

Marine fossils were collected from the tuff beds exposed on Doone Creek and on the creek north of it. These have been identified by T. W. Stanton as follows:

6693. Creek entering Chickaloon River from west 1 mile above Government Bridge. Elevation, 2,200 feet.
Rhynchonella sp.
Pecten sp. a. Smooth form.
Pecten sp. b. Strongly ribbed Vola type.
Pecten sp. c. Large, flat, coarse-ribbed form.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 16-19.

6697. Doone Creek, at mouth of gulch, 3,950-foot point, traverse of August 30. Float.
    Rhynchonella sp.
    Pecten sp. a.
    Pecten sp. b.
    Pecten sp. d.
    Trigonia? sp.
    Cardinia? sp.
    Deroceras? sp.
    Ægoceras? sp.

6706. Creek entering Chickaloon River from west 1 mile above Government Bridge. Elevation, 2,000 feet.
    Pecten sp. b.
    Deroceras? sp.

6707. Creek entering Chickaloon River from west 1 mile above Government Bridge. Float from base of falls.
    Rhynchonella sp.
    Gryphæa? sp.
    Ostrea sp.
    Pecten sp.

Probably Jurassic.

6708. Creek entering Chickaloon River from west 1 mile above Government Bridge. Float above falls.
    Pecten sp.
    Several undetermined small pelecypods.

Possibly Jurassic.

6709. On same creek as 6,708 at elevation 2,200 feet. From talus.
    Cardinia? sp.

Jurassic.

AGE AND CORRELATION.

The following statement concerning the age and correlation of the fauna found in these beds has been submitted by T. W. Stanton:

> The lots numbered 6693, 6697, 6706–6709 are referred to the Jurassic and are probably Lower Jurassic, though the paleontologic evidence for the latter reference is not so full as is desirable. The fossils are almost certainly from the same beds from which Mr. Knopf collected his lot No. 201, on the head of Matanuska River, in 1906. Mr. Knopf's collection was at that time doubtfully referred to the "Enochkin formation," but I am now inclined to consider the beds from which he collected equivalent to the supposed Lower Jurassic near Seldovia and to regard them as Lower Jurassic. It is true that not more than two or three species have been found common to the different localities from which these fossils have been collected, but the general character of the fauna in each case is suggestive of Lower Jurassic, and it is probable that more systematic collecting would prove that the different lots really belong to a single fauna.

The fossils collected by Knopf and referred to by Stanton in the preceding paragraph have been described as follows:[1]

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 18.

The fossils found in tuffs associated with the greenstones were submitted to T. W. Stanton, who reports as follows:

6 A. K. 201. Fossiliferous tuffs, associated with lavas and coarse pyroclastics, from the head of Matanuska River:

Rhynchonella.
Lima.
Pecten. Smooth species.
Pecten. Species of Vola type.
Trigonia.
Astarte?
Protocardia.
Pleuromya.
Sonninia?

The Jurassic age of this lot is clearly shown by the form of the Trigonia and of the ammonite (Sonninia?). The general aspect of the fauna is that of the lower part of the Enochkin,[1] though it may be somewhat older than the fauna in lots 88A and 88B. With the exception of the Vola-like species of Pecten there is nothing in it to suggest the Lower Jurassic fauna of Seldovia.

The assignment of this fauna to the Lower Jurassic rather than to the Middle Jurassic is in harmony with the fact that the Middle Jurassic of Cook Inlet[2] is not known to contain volcanic beds, while the Lower Jurassic of Cook Inlet[3] does contain volcanic beds of lithologic character strikingly similar to that of the beds here under discussion.

LOWER CRETACEOUS (?) ROCKS.

LIMESTONE.

AREAL DISTRIBUTION.

Limestone occurs north of Castle Mountain in a belt within which there is one large area and at least three smaller ones. The best exposures are on the ridge north of the west end of Castle Mountain. Other exposures were seen at the head of Doone Creek and on the next creek north of it.

LITHOLOGIC CHARACTER.

The limestone, as seen on the ridge north of the west end of Castle Mountain, is blue and gray to white, of fine to medium grain (crystallinity), much shattered and full of minute calcite veins, and as seen on top of the ridge well bedded (in beds 6 inches to several feet thick) without decided change in lithology from bed to bed. The westernmost exposure on top of the ridge, a small, isolated outcrop at an elevation of 4,700 ± feet, contains beds which are decidedly cherty.

---

[1] The lower part of the Enochkin formation is now known as the Tuxedni sandstone.

[2] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region: Bull. U. S. Geol. Survey No. 485, 1912, pp. 59-68.

[3] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 20-22.

The limestone exposed on the creek north of Doone Creek is at the bend about a mile above the mouth of the creek. The exposure is in the form of a vertical comb of crystalline cherty limestone at least 50 feet thick. The trend of the vertical mass, which is possibly the strike of the limestone, is N. 45° E. No bedding was recognized. The rocks on the east side are concealed by a moraine. West of the limestone outcrop is a mass of sticky reddish clay.

The grain of this limestone ranges from subcrystalline to that of loaf sugar. It is mostly white, though numerous pinkish masses were seen. The pink color is largely, but not altogether, on the surface. Masses of chert and cherty limestone are abundant. No clearly bedded masses of chert were recognized. The appearance of the rock suggests that whatever bedding it once possessed is now entirely destroyed by the shattering and recrystallization which it has undergone.

STRATIGRAPHIC RELATIONS.

The limestone on the crest of the ridge north of Castle Mountain lies in a closely compressed overturned syncline and rests upon somewhat altered volcanic rocks which are considered to be the same as the Lower Jurassic volcanics with which they are areally continuous. (See Pl. XV, p. 72.) An exposure on the west end of this ridge shows the rocks in direct contact and small pebble-like fragments of the greenstone embedded in the lower 2 inches of the limestone. These fragments give evidence that the limestone overlies the greenstone unconformably.

AGE AND CORRELATION.

No fossils have been found in the limestone of the district here described, so the determination of its age depends on the local stratigraphic evidence and on correlation with the rocks of neighboring regions.

It has already been shown that the limestone rests unconformably upon Lower Jurassic rocks. The Middle and Upper Jurassic rocks of the upper part of the Matanuska Valley show a complete sequence of several thousand feet of strata in which limestones are absent. The Upper Jurassic is overlain, on Billy Creek and Nelchina River, by a massively bedded limestone at least 300 feet thick, at the base of which[1] are Lower Cretaceous fossils. Although there are differences in the features of the two limestones, they are such as might be explained by the fact that the two occurrences are 25 miles apart and in structurally different areas. These limestones are here provisionally correlated and referred to the Lower Cretaceous.

---

[1] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 308-309. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 24.

UPPER CRETACEOUS ROCKS.

AREAL DISTRIBUTION.

The Upper Cretaceous rocks cover a large area in the central part of the region here described. They include all the exposures of hard rock in the banks of Matanuska River from a point 2½ miles below Chickaloon River to Moose Creek and occupy all of the valley of Granite Creek 6 miles above its mouth, much of the upper part of the valley of Young Creek, the west side of the valley of Kings River from 6 to 10 miles above its mouth, the low hills between Kings River and the Matanuska, and a small area in the valley of Carbon Creek.

LITHOLOGIC CHARACTER.

The rocks consist of shale and sandstone, having an aggregate thickness of at least 4,000 feet, of which the lower half is practically all shale and the upper half consists of alternating beds of sandstone and shale, the former predominating. Conglomerate is present, but not in thick or abundant beds. The most complete observed section is in the gorge of Granite Creek and is recorded below. Other good sections are exposed on Kings River between the main trail and the coal camp and in the cliffs of Matanuska River. Many of these cliffs are not accessible for close study except at a very low stage of the water.

Section in Upper Cretaceous rocks on Granite Creek, beginning at lower end of canyon, 1¾ miles from the mouth of the creek.

	Feet.
Black shale at base, overlain by thin-bedded gray sandstone, some of which is very fine and has contorted laminæ, and gray or drab-gray shales (beds are interleaved lenses rarely more than 6 inches thick)	12
Black sandy shale	4–6
Thin-bedded gray sandstone and shale	15
Black nodular shale	8
Sandstone, mainly thick beds about 5 feet thick, with thin interbedded shales	30
Interbedded black shale and thin gray sandstone and shale	50
Massive sandstone, feldspathic and micaceous	20
Interbedded gray shale, gray sandstone, and black shale	40
Sandstone	12
Alternating beds, 1 to 8 feet thick, of gray sandy shale and black shale	250
Similar beds increasingly to dominantly sandy and light gray	80
Dark-colored sandstone and sandy shale	75
Light-gray sandstone including several thick, massive beds and some very thin shales (in east bank; estimated thickness)	200
Dark shale in beds alternating with thin sandstones and light-colored shale	450

	Feet.
Sandstone, heavy bedded at the top but dominantly thin bedded (beds 1 to 2 feet and less than 1 foot), with many beds of very thin shaly sandstone having contorted laminæ; also a few thin shale beds and an increasing number of dark shales in the lower part	840
Exposures interrupted and inaccessible for 1,500 feet along the creek, equivalent to an estimated stratigraphic interval of	500
Dark bluish-black sandy shales outcropping for 200 feet in a direction about N. 17° E.; strike N. 40° E.; dip, 60° SE.; computed thickness	80±
Exposure interrupted and inaccessible for 800 feet along the creek, equivalent to an estimated stratigraphic interval of	300±
Hard dark blue-black shale,[1] outcropping for about 200 feet in a direction N. 17° E.; strike, N. 28° E.; dip, 60° to 65° SE.; computed thickness	90±
Exposure interrupted and inaccessible for about 200 feet along the creek, equivalent to an estimated stratigraphic interval of	90±
Hard dark blue-black shale,[1] outcropping for 400 feet along the creek in a direction N. 17° E.; strike, N. 47° E.; dip, 50° SE.; computed thickness	170±
Exposure interrupted and inaccessible for 100 feet along the creek, equivalent to an estimated stratigraphic interval of	45±
Hard dark blue-black shale,[1] outcropping for about 1,000 feet along the creek; estimated thickness	400±
	3,760±
No exposure for 7,500 feet.	
Several small outcrops through 1,200 feet along the east bank of the creek in a northerly direction; strike, N. 23° E.; dip, 49° SE.; computed thickness	350±

The section on Granite Creek was measured in the gorge that begins 1¾ miles above its mouth and extends northward for 2 miles; in this distance exposures are almost continuous on one or the other bank, and in some places on both banks of the stream. It is assumed, in accepting this section and thickness, that there is no repetition of the beds by faulting. The exposures are not of such a character as to make this an absolutely safe assumption, although the absence of observed faults, or of beds which seem to be repeated, and the fact that the ridge on the east of the gorge presents an unbroken dip slope, suggest that the section is an uninterrupted and unrepeated monoclinal succession of beds.

The rocks exposed in the gorge of Granite Creek are southeastward-dipping sandy shales and flaggy sandstones. Inoceramus and other Upper Cretaceous fossils were collected from the shales of the lower part of the section, in the positions indicated. The sandstones, which predominate higher in the section, yielded no fossils except a fragmentary nuculoid form. No plant fossils were seen.

---

[1] Fossils collected from these beds are lot 6680; see p. 37.

These rocks differ lithologically from the Tertiary rocks of the region in that the shales are considerably more indurated than the Tertiary shales. The Upper Cretaceous shales are prevailingly black—markedly so in the lower half of the section; the Tertiary shales are prevailingly gray, being black only where they are highly carbonaceous, and there containing many thin coal streaks. The Upper Cretaceous shales break on clearly defined bedding and joint planes; the Tertiary shales break into shapeless masses. The former weather into masses of undecomposed shale pieces, on which bedding and either joint planes or conchoidal fractures determine the sharp edges of the fragments. The latter break down into small, nonplaty, shapeless masses and dust. The Upper Cretaceous sandstones are darker, less inclined to be arkosic, more indurated (that is, in general, although some beds in the Tertiary are very hard), and more evenly bedded. Very fine grained laminated micaceous and flaggy sandstones are characteristic of the Upper Cretaceous rocks. The thin laminæ of these fine-grained sandstones are irregularly contorted. Other criteria for distinguishing these rocks from the Tertiary rocks are the absence of coal and the rarity of fossil sticks and of leaves, the presence of fucoidal markings in sandstones and of marine fossils in the shales, the presence of thin beds and nodules of very hard reddish-weathering sandstone with curved bedding, the greater amount of shattering, and the greater abundance of thin calcite veins. Beds of finely conglomeratic sandstone with scattered subrounded black pebbles from the size of bird shot to that of a pea are present in and are characteristic of the older rocks.

The features described below, shown at an exposure of bluish-black shale in the gorge of Kings River 8,000 feet above the bridge on the main trail, are characteristic of the dark shales that form the lower part of the Upper Cretaceous section. Although the rock looks slaty on large exposure, when struck or when a mass falls it breaks into irregular lathlike pieces several inches long, an inch or two in width, and half an inch to an inch thick, owing to a very uneven jointing perpendicular to the bedding. Perpendicular both to this jointing and to the bedding is the major jointing, which is very well defined. The shale contains numerous hard nodules from half an inch to 10 inches in diameter. These appear to consist of the same material as the shale. In places they weather out, leaving an iron stain. No leaves or carbonaceous material were seen.

FAUNA AND FLORA.

These rocks possess a distinctive marine invertebrate fauna which has been recognized by the presence of abundant Inoceramus at many localities. The fossils are more abundant in the shales which make up the bulk of the lower part of the formation, although Inoceramus was seen in the higher sandy beds.

The following lists of fossils were submitted by T. W. Stanton:

6689. Granite Creek, west bank, between elevations of 1,000 and 1,050 feet:
Rhynchonella? sp.
Inoceramus sp. Very large compressed form which has been collected on Alaska Peninsula north of Aievak or Douglas village.
Inoceramus sp. Related to I. labiatus.
Upper Cretaceous.

6690. North bank of Matanuska River, at lower end of lower gorge 1.1 miles north of Moose Creek:
Inoceramus sp.
Upper Cretaceous.

6691. East bank of Kings River at Coal Camp:
Inoceramus sp. Fragment of large, flat species.
Upper Cretaceous.

6692. Pass between Kings River and Young Creek:
Rhynchonella? sp.
Inoceramus sp.
Upper Cretaceous.

6694. Kings River, east bank, three-fourths of a mile below U. S. L. M. No. 1.
Ostrea sp.
Inoceramus sp. Large, compressed species, as in lot 6689.
Diplomoceras notabile Whiteaves?? Fragments of a large specimen.
Upper Cretaceous.

6695. North bank of Matanuska River, at upper end of lower gorge at mouth of Eska Creek:
Inoceramus sp. Fragment.
Probably Upper Cretaceous.

6696. Creek entering Granite Creek from west 5 miles above main trail, about half a mile west of and 470 feet in altitude vertically above Granite Creek.
Inoceramus sp. Probably young of large species in lot 6689.
Phylloceras sp.
Nemodon? sp.
Amberleya sp.
Pachydiscus sp.
Desmoceras sugata Forbes?
Desmoceras? sp.
Anisoceras? sp.

This collection is clearly of Upper Cretaceous age and belongs to the general Indo-Pacific fauna, which is well developed in India, Japan, Sakhalin, Vancouver, and California.

6699. 3,350-foot knob 1 mile north of east end of Chain Lakes:
Fragment of an undetermined echinoid.
Horizon not determinable.

6700. East bank of Kings River 0.35 mile above mouth:
Inoceramus sp.
Probably Upper Cretaceous.

6701. North bank of Matanuska River 3½ miles east of mouth of Kings River:
Inoceramus sp.
Probably Upper Cretaceous.

6702. East bank of Kings River one-fourth of a mile above its mouth:
Inoceramus sp.
Probably Upper Cretaceous.
6703. Kings River, east bank, 3,850 feet below mouth of Little Kings.
Inoceramus sp.
Probably Upper Cretaceous.
6704. Carbon Creek 3,875 feet above mouth:
Inoceramus sp.
Probably Upper Cretaceous.
6705. Young Creek, in float:
Inoceramus sp.
Probably Upper Cretaceous.

Some fossils of more or less problematic character were seen in the sandstones on Kings River, on Coal Creek, and elsewhere, in association with large shells and fragments of Inoceramus. The following report on specimens from Kings River has been submitted by Arthur Hollick.

5893, 5894. "Kings River, at Coal Camp:"
Remains and markings of uncertain identity. One specimen appears to be a Spirophyton. Others may be worm tracks or burrows.
Age not determined.

Fossil plants of species unlike those in the local Tertiary formations were collected from beds which lie a short distance below the contact with the diorite mass west of Kings River and which were regarded as occurring in the upper sandy part of this formation. The following report on this collection was made by Arthur Hollick:

5898. "Locality (34) at south of pond on top of mountain between Kings River and Young Creek, 1½ miles N. 10° W. from Kings River Bridge:"
Equisetum arcticum Heer? Specimens very fragmentary. Some pieces might equally well be referred to E. robustum Newb.
Glyptostrobus ungeri Heer? Fragmentary remains of a heterophyllous conifer, some of which might equally well be referred to Juniperus tertiaria Heer.
Nyassa arctica Heer.
Aristolochia sp. This is in great abundance and is very variable in form. Some specimens are hardly to be distinguished from certain forms of Populus arctica Heer.
This is a meager and more or less unsatisfactory collection. The general facies is different, however, from that of any other collection from the Matanuska field. Age, basal Eocene.

AGE AND CORRELATION.

The marine fauna contained in these rocks shows that they are of Upper Cretaceous age. T. W. Stanton has submitted the following statement regarding the age and relation of this fauna:

Of the lots referred to the Upper Cretaceous those numbered 6689, 6694, and 6696 are certainly of that age and belong to the Upper Cretaceous fauna which has been recognized at several points on the Alaska Peninsula and is part of the general Indo-Pacific fauna found in the Chico formation of California, on Vancouver Island, in Japan, and in India. Most of the other lots in this collection, referred to the Cretaceous, contain only fragmentary specimens of Inoceramus which are not sufficient in themselves for discrimination between Jurassic and Cretaceous, though it is probable that these fragments belong to the same species that occurs at other localities in the neighborhood where the Cretaceous age of the rocks is definitely determined.

The problematic fossils occur in immediate association with a large form of Inoceramus and are thus known to be Mesozoic, and as they are found above the horizons at which the more characteristic Upper Cretaceous fauna occurs, they are consequently Upper Cretaceous also. They are not sufficiently characteristic to yield of themselves independent evidence on the age of the rocks.

The fossil plants of lot 5898 were collected from beds which are stratigraphically above the highest beds containing observed marine Cretaceous fauna but which are lithologically identical and apparently stratigraphically conformable with them and are lithologically unlike any of the known Tertiary beds of this region. These beds are considerably more indurated than any of the local Tertiary rocks except those which have been involved in the intense deformation in the mountain region north of the Matanuska Valley. The field relations consequently indicate, though they do not prove, that this flora is older than the Tertiary floras described below and suggest that it belongs in the Upper Cretaceous. The flora is somewhat different in character from the known Tertiary floras but is, nevertheless, more like them than it is like any known Mesozoic floras.

TERTIARY ROCKS.

The Tertiary rocks consist of three sedimentary formations overlain unconformably by basaltic lavas and tuffs and intruded by many dikes, sills, and stocks.

ARKOSE, CONGLOMERATE, AND SHALE.

AREAL DISTRIBUTION.

The rocks grouped under the above heading are found in a belt extending along the northern border of the Matanuska Valley from the Little Susitna to Chickaloon River. They are known to occupy a considerable area in the Talkeetna Mountains between Granite Creek and Kings River and probably occur at other points within the mountains. They have not been recognized south of the great fault, which, throughout the area represented on the detailed map (Pl. V, in pocket), marks the northern edge of the Matanuska Valley proper.

LITHOLOGIC CHARACTER.

The arkose, conglomerate, and shale are highly indurated, in this respect, as in other lithologic characteristics, differing from the other Tertiary rocks, described on pages 42–54.

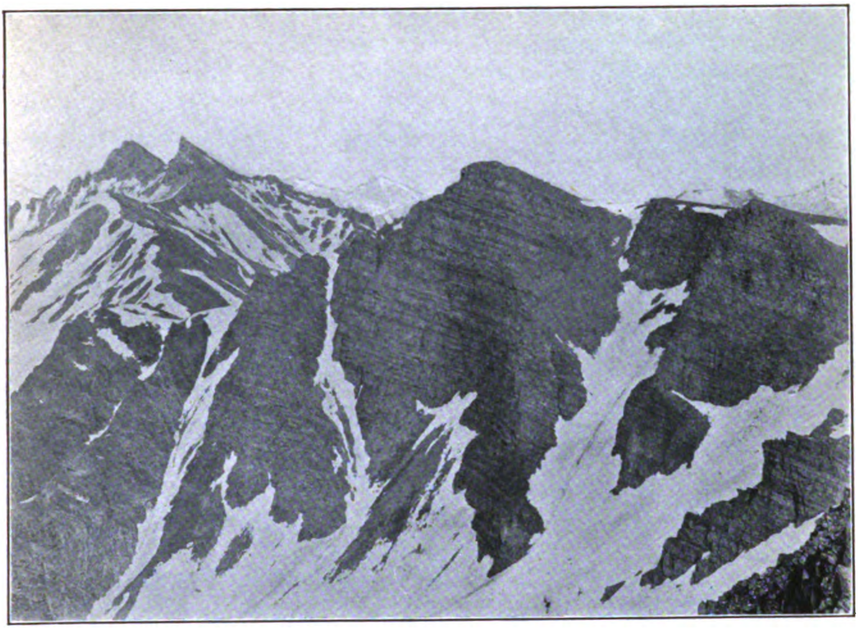
The rocks exposed in the ridge north of Moose Creek are principally arkose, with a few beds of shale. The arkose is fine grained and conglomeratic in places, but the conglomeratic feature nowhere predominates. The rocks have a dark-brown to gray color and contain all the essential constituents of granite. Quartz, feldspar, hornblende, biotite, and chlorite can be easily recognized. Locally the feldspar is much kaolinized. The chlorite gives the whole rock in places a greenish tinge. Much of the arkose somewhat resembles an igneous rock. Some of it is so much like granite in appearance that its sedimentary character is recognizable only by a few rounded pebbles and carbonized plant remains. On the other hand, the arkose grades into conglomerate so that no definite line can be drawn between them.

The exposures on the northern slope of the ridge (see Pl. VIII) show a thickness of over 1,500 feet of bedded rocks with no faulting. The outcrops on the crest of the ridge consist in some places of cross-bedded granitic arkose and in others of fine-grained conglomeratic arkose with small amounts of sandy shales and micaceous sandstones.

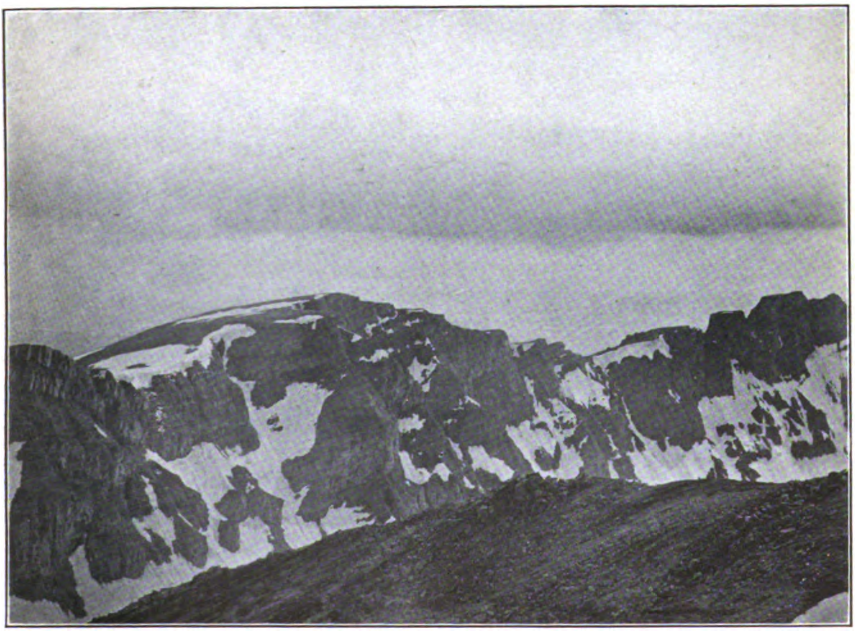
The conglomerates seem to be best developed north of Castle Mountain, where they are faulted against the Eska conglomerate, giving an excellent opportunity for the recognition of the essential lithologic characteristics of each formation. The following is a description of beds exposed in the creek entering Chickaloon River from the west a mile above the Government bridge. This creek emerges at an elevation of about 1,500 feet from a gorge with overhanging walls of sandstone and conglomerate. The conglomerate is the fine-pebble, well-indurated kind seen in Doone Creek north of Castle Mountain. The pebbles are mostly under 1 inch, though a few are 2 or 3 inches in greatest dimension, and are mostly of quartz and dark quartzite, the latter most abundant. They are not well rounded and are set in a matrix of fine conglomerate or coarse grit. The sandstone is more indurated than that of the Chickaloon formation and resembles more closely some of the sandstones of the Upper Cretaceous.

Conglomerate extends up the creek to an elevation of 1,660 feet, giving a thickness of several hundred feet. It becomes coarser upstream, containing numerous pebbles 3 to 5 inches in length. Some 4-inch pebbles of shale were seen. At no point do these beds resemble those of the Eska conglomerate.

At elevation 1,660 feet there is a sharp (fault?) contact of conglomerate with shale which resembles that of the Chickaloon formation, but is somewhat more indurated. The bedding of both rocks and the contact plane are vertical. The contact strikes N. 55° E. The shale is of no great thickness and is succeeded a short distance upstream by conglomerate.



A. EXPOSURE OF ARKOSE IN CLIFFS ON NORTH SLOPE OF RIDGE NORTH OF MOOSE CREEK.



B. GENTLY DIPPING ARKOSE IN WEST END OF RIDGE NORTH OF MOOSE CREEK.

The crest of the ridge shows remnants of old smooth topography into which glacial erosion has cut cirques

Conglomerate, sandstone, and shale in rapid alternation extend from elevation 1,660 feet to 1,780 feet. The conglomerate predominates in the exposures, but the three rocks are probably of about equal bulk.

At elevation 1,780 feet is an exposure of much broken sandy shale, some beds of which are very carbonaceous. One or two beds, now reduced to a crushed mass, are so black as to suggest that the beds were coal or coaly. These are less than 1 foot thick.

STRATIGRAPHIC RELATIONS.

The arkosic rocks rest upon an approximately even surface of granite, this contact being at all observed points parallel to the bedding of the sediments. The contact in the mountain west of Kings River at the edge of the area shown on the detailed map (Pl. V, in pocket) is at an elevation of about 4,500 feet and, like the bedding of the arkose at this point, is practically horizontal. The rocks are more steeply folded in the valley west of this mountain and in the ridge north of Young Creek, but the dips, which are dominantly northwest, are essentially parallel to the basal contact with the granite. The same condition exists in the ridge north of Wishbone Hill except that the bedding and the contact with the granite are both steeply inclined toward the south. Similar conditions apparently exist on the ridge north of Moose Creek. (See Pls. VII, *B*, p. 28; XIV, *A*, p. 72; and XV, p. 72.)

The contact of the base of the arkosic rocks with the granite is a sedimentary contact. The evidence for this statement consists in the uniform parallelism of the contact with the bedding, in the absence of any recognized marginal facies in the granite or of any apophyses from it, in the presence in the arkose of detritus similar to the granite in composition, and in the absence of any contact metamorphism in the sedimentary rocks. The lack of evidence that there are granites anywhere in Alaska which are young as this arkose is corroborative evidence that this granite is not intrusive into the arkose.

The arkosic rocks are also in contact with the other Tertiary rocks and with the Cretaceous and Jurassic sedimentary rocks. These contacts, so far as observed, are faults. (See Pls. XV and XVI, p. 72.) The absence of any observed sedimentary contacts of the arkosic rocks with the Upper Cretaceous rocks which should underlie them or with the other Tertiary formations which, it is believed, should overlie them leaves the exact stratigraphic position of these beds more or less in doubt. These rocks have been separated from the other Tertiary sedimentary beds described below on the basis of their predominantly arkosic character, greater degree of induration, and absence of coal. There is little doubt that these rocks are for the most part low in the local Tertiary sequence and include the basal beds, although possibly the assemblage represented on the map includes in part the marginal facies of some beds higher in the Tertiary, as well as higher beds not necessarily marginal but now occurring in structural zones in which they have been deformed to a degree not permitting their separation from the basal or marginal deposits. The thickness of these beds exceeds 2,000 feet.

FLORA.

Fossil plants are abundant in many of the shaly beds of this group of rocks, but are in general not well preserved on account of the intense deformation which the rocks have undergone. The following species were identified by Arthur Hollick from material collected by the writers in 1910:

5900. Sheep Valley, 6½ miles N. 7° E. of mouth of Kings River, elevation 4,400 feet:
    Populus arctica Heer.
    Quercus platania Heer.
  Age, "Arctic Miocene" (Eocene).

Paige and Knopf collected the following species, which were identified by F. H. Knowlton, in 1906:

Arkose Ridge, north of Moose Creek:
    Taxodium distichum miocenum Heer.
    Taxodium tinajorum Heer.
    Populus sp.?
    Ficus? grönlandica? Heer.
    Paliurus colombi Heer.
    Fruits, cf. Leguminosites sp.
  Age, apparently Kenai.

CHICKALOON FORMATION.

AREAL DISTRIBUTION.

The Chickaloon formation covers the greater part of the valley of Chickaloon River, south of Castle Mountain, or south of a point about 5 miles in an air line above the mouth of that stream. This area extends west to Kings River, the same formation occupying the eastern bank of Kings River between points about 6 miles and 8 miles above its mouth. It also extends south of Matanuska River from a point 2½ miles below the mouth of Chickaloon River at least to a point 4 miles above its mouth, and it extends east of the area which was mapped for an unknown distance, possibly as far as the mouth of Hicks Creek.

The same formation occurs in three small detached areas in the valley of Kings River, one of which is on the banks of Kings River from 5 miles to 6½ miles above its mouth and the other two are on

Young Creek near its mouth and in the upper part of its valley. The outcrops in the areas near the mouth of Young Creek and on Kings River 6 miles above its mouth are possibly parts of the same mass, the apparent discontinuity being due to the presence of a gravel sheet, which conceals the underlying rocks except in cliffs.

The Chickaloon formation is also exposed in the banks of Eska Creek, on Moose Creek, and on the north bank of Matanuska River for about a mile below the mouth of Moose Creek. These exposures are probably all parts of one general body, much of which is covered by gravels.

LITHOLOGIC CHARACTER.

The Chickaloon formation consists of a rather monotonous succession of shales and sandstones. The shales, which predominate over the sandstones in aggregate thickness, are gray to drab, rather soft and inclined to disintegrate on exposure, poorly bedded, and without well-defined joint planes. Most of the beds are rather gritty and vary in grain along the bedding. They contain many nodules and lines of nodules of iron carbonate, some of which form fairly persistent beds. The sandstones are yellowish, rather soft, of diverse grain in the different beds and of varying grain in the same bed, and for the most part feldspathic; in general, the individual beds are not very persistent. The thickness of the formation is doubtful but appears to be at least 2,000 feet.

Fossil leaves are present in both the shales and the sandstones, and are especially abundant and well preserved in the beds carrying iron carbonate.

The coal beds are numerous. There is no evidence as to their exact position within the formation or as to the persistence of individual beds or groups of beds.

The sections given on the following pages are typical of the lithologic character, although none of them represent anything near the full thickness of the formation nor is their exact position within the formation known.

Section in the Chickaloon formation at the bend of Chickaloon River half a mile above Chickaloon coal camp.

	Ft.	in.
1. Gray shale with occasional concretions	16	
2. Hard clay shale, nodular	2	6
3. Fissile gray shale with iron balls	16	
4. Dark-gray limestone	1	
5. Dark fissile shale	4	6
6. Micaceous sandstone	2	6
7. Dark liver-colored fissile shale containing strata of iron concretions	2	
8. Arkose	1	
9. Dark fissile shale	12	
10. Iron ore		3

		Ft.	in.
11.	Black shale		9
12.	Carbonaceous shale and bone		6
13.	Black shale	3	
14.	Dark fissile shale with many strata of ironstone nodules	33	
15.	Carbonaceous shale	2	
16.	Dark shale with thin strata of ironstone balls	23	
17.	Ironstone with fossil gastropods [1]		6
18.	Dark shale with many streaks of iron ore	6	
19.	Soft black carbonaceous shale	6	
20.	Ironstone		6
21.	Dark fissile shale with bands of ironstone	35	
22.	Massive sandstone	10	
23.	Black shale		6
24.	Coal, with some bone and shale [2]	14	
25.	Shale and sandstone	10	
26.	Coal, with some bone and shale	8	9
27.	Dark shale	6	
28.	Dark shale with coal streaks	2	
29.	Shale with sandstone and ironstone bands	19	
30.	Sandstone with sandy shale bands	9	
31.	Shale	1	
32.	Coal, impure, much distorted and changed by heat	5	6
33.	Shale with iron bands	9	
34.	Sandstone (in roll)	4	6
35.	Shale	7	
36.	Diabase sill, with local occurrence of natural coke on top	11	
37.	Irregular mass of coal and carbonaceous matter much distorted by the sill	15	
		300	3

Section in the Chickaloon formation beginning at east end of the outcrop in the bluff at Chickaloon coal camp.

	Ft.	in.
Coal bed	15+	
Gray shales with ironstone bands and nodules; lower 6 feet thickly packed with large nodules	21	
Carbonaceous shale	1	6
Coal bed [3]	8	3
Shales and sandy shales with many sandstone lenses and ironstone nodules [4]	27	3
Gray shale	7	8
Carbonaceous shale with thin coal streaks		9
Sandy shale and sandstone with ironstone	8	6
Fissile carbonaceous shale	1	2
Coal bed [5]	4	6
Shales with many ironstone bands	21	6
Coal, clean, bright	1	8
Shaly sandstone	1	5
Coal with shaly bands	1	2

---

[1] Fossils in lots 3316 and 6698 (see p. 52) were collected from this bed.

[2] This bed and the bed at the top of the following section are at about the same horizon and probably are the same bed.

[3] This is the lowest coal represented in section 9 (p. 79), at the entrance of tunnel A. It is also the lowest coal bed in section 13, tunnel 2 (p. 80).

[4] This is the lowest shale bed in section 11 (p. 80), at the entrance of tunnel B.

[5] This is the lowest coal in section 15 (p. 80), near the entrance of tunnel 3.

	Ft.	In.
Largely concealed, chiefly shale[1]	10	10
Hard sandstone; weathers rusty		9
Gray shaly sandstone	1	6
Bluish nodular shale with sandy lenses and ironstone nodules	12	9
Coal	7	6
Coal and shale	4	4
Black waxy shales with thin coaly streaks, sandy at top	2	9
Gray sandy shales[2] (one-eighth inch coal streak near top) (Continuity doubtful.)	10	
Dirty coal and carbonaceous shale with thin coal lenses	2	4
Gray sandy shales with many bands of ironstone nodules, grading laterally into massive gray sandstone	30	
Coal, varying greatly in character along strike and containing large silicified sticks	1	3
Gray shale and ironstone nodules	9	7
Concealed	25	
Gray shale with thin carbonaceous shales, ironstone nodules and sandstone lenses	10	6
Coal and carbonaceous shale		9
"Waxy" carbonaceous shale		6
Gray shale with ironstone nodules	7	6
Coal bed[3]	7	11
Nodular gray shale, ironstone concretions in band at base	7	
Gray shale as above poorly exposed	19	6
Concealed but probably gray shale with ironstone and a little carbonaceous shale containing coal streaks	28	
Coaly shale and coal, in places bony		5–8
Gray shale with ironstone nodules and sandy lenses	9	6
Carbonaceous and sandy shales and sandstone, partly concealed.	11	6
Shale	7	
Sandstone	2	9
Thin beds of sandstone with 6 inches of ironstone	4	4
Carbonaceous, fissile shale with small coal lenses, 2 inches or less thick, much crumpled	8	
Sandy nodular shales with large sandstone lenses and large ironstone concretions	29	
Gray nodular shales and carbonaceous shales with short lenses of coal up to 2 inches thick	0–2	6
Gray nodular and sandy shales, fissile and carbonaceous at the top, grading laterally into and interleaved with shaly sandstone containing numerous ironstone nodules	19	6
Dark-bluish nodular shale chiefly, with carbonaceous shale and thin coal lenses, sandstone lenses, and ironstone nodules	8	
Bluish dark leaf-bearing shale with very thin coaly streaks and several ironstone bands laterally overlapping sandstone lens	7	9
"Waxy" fissile carbonaceous shale		4
Shaly sandstone and shales with ironstone nodules, varying rapidly in character laterally	9	9
Fissile carbonaceous shales, with coaly streaks, gray sandy shales, and ironstone	9	3
Nodular sandy shales with several bands of ironstone concretions.	11	6
Gray sandstone, grading laterally into sandy shales, and large ironstone nodules	9	10

---

[1] This bed is probably the same as the shale at the entrance of tunnel C. (See section 16, p. 80.)

[2] Tunnel D (see section 17, p 81) begins near the base of this bed.

[3] Detailed measurements of this bed are given in sections 18 and 20 (p. 81).

	Ft.	in.
Sandy shales and ironstone nodules	7	3
Sandy shales with small coal streaks and lenses and a few small ironstone nodules; carbonaceous shale at top	4	9
Sandy shales and thin sandstone lenses	9	
Gray speckled sandstone with carbonized plant remains and bits of coal	3	4
Dark leaf-bearing and gray shales containing thin bands of ironstone nodules and a lens of coked shaly coal at base	8	
Diabase sill.		
Gray shale	1	10
Sill (probably not extensive). Below this sill the exposure is continued in the cliff along Chickaloon River but is more or less concealed by slide or is inaccessible.		
Gray sandy shales and dark carbonaceous shales and thin sandstones containing a 15-foot sandstone bed and several diabase sills; estimated thickness	200	
Heavy diabase sill.		
Shales, dominantly gray and concretionary, with intercalated sandstone beds and lenses and ironstone concretions; computed thickness	30	
Diabase sill.		
Gray sandy and concretionary shales with five or more thin ironstone bands and thin lenses of sandstone in lower part; computed thickness	104	
Gray sandstone	4	3
Sandy shales and thin sandstones	28	
Diabase sill.		
Thin-bedded and slightly cross-bedded sandstone	13	6
Shale	1	
Concealed.		
Shale (including 5½-foot sill); estimated thickness	90	
Concealed	40	
Dark-gray and brownish shales with ironstone nodules and in part sandy; computed thickness	176	
Concealed.		
Gray thin cross-bedded sandstone and sandy concretionary shale.	20	
Sill.		
Dark-gray shale with ironstone band	4	
	1,218	
Concealed.		
Sill.		

A similar succession of beds is repeated through the remaining 1½ miles down Chickaloon River, but could not be measured or reliably estimated because of the folding of the beds and the recurring interruptions of the outcrop. The above section is over 1,200 feet thick, and in the lower 1½ miles of Chickaloon River and along Matanuska River below the Chickaloon there is perhaps as much more exposed.

On Boulder Creek from a point at about the east edge of the area shown on the detailed map down to a point half a mile above the mouth of the creek there is a nearly continuous exposure of the Chickaloon formation in which there is no sign of interruption or repeating of beds. Neither the top nor the base of the formation is exposed. The strike and dip are nearly uniform, averaging N. 76° W., 34° NE., through 6,400 feet in a direction N. 83° E. From these figures the thickness of the section is estimated at 1,240 feet.

On a creek tributary to Chickaloon River opposite Boulder Creek, from a point about 8,000 feet above the mouth of the creek to a point about 2,000 feet farther upstream, is a continuous section approximately 1,060 feet thick. The lower half consists chiefly of light-colored sandy shales; the upper half is made up principally of dark shales with thin sandstone beds and many thicker beds of carbonaceous leaf-bearing shales which include numerous minute coal lenses. Several fossil logs and tree stumps, one of which is 20 feet long and stands normal to the bedding, were seen. Below this section the exposures are interrupted and the structure is not uniform, but it is certain that there are at least 200 feet of lower beds into which two or more considerable sill-like masses of gabbro are intruded. Above this section there are several hundred feet of sandstones, shales, etc., below the base of the Eska conglomerate in Castle Mountain. In this section no important coal beds were seen, and it is presumably above that part of the Chickaloon formation appearing in the section along Chickaloon River. (See pp. 43–46.)

Section in the Chickaloon formation on the east bank of Kings River at the bend below the coal camp.

	Ft.	In.
Porphyry sill.		
Dark shale	51	6
Sill of fine-grained basic rock.		
Dark shale with ironstone nodules	16	
Coal bed [1]	3	9
Carbonaceous shale	1	2
Gray shale with ironstone nodules near base	3	6
Sandstone and sandy or concretionary shale	3	4
Gray concretionary shale	4	4
Coal bed [1]	1	3
Gray shale with ironstone nodules	15	
Gray shale, becoming sandy toward base	6	
Shale and sandstone	5	3
Gray shale with ironstone nodules	37	
Ironstone	1	
Shale	3	8
Sandstone	1	3
Shale with ironstone concretions and some sandstone	6	3
Gray shale	15	
Concealed	10	
Sandstone	8+	
Shale with concretions	45	
Coal bed [1]	17±	

---

[1] For details see coal section 21, p. 81.

Section in the Chickaloon formation on Eska Creek 1,100 feet below the forks.[1]

	Ft.	in.
Sandstone	75±	
Shale	1	
Coal		1½
Shale		2
Coal	2	1
Coal, dirty coal, coaly shale, and shale	13	2
Shale	8	
Thin interbedded coal, shale, and coaly shale; dominantly coal	11	7
Shale	3	9
Shale with thin bands of coal	4	2
Thin interbedded coal and shale with thin ironstone bands; dominantly coal	12	5
Shale with some ironstone	13	4
Coal and shale	2	7
Shale	3	
Coal and shale; dominantly coal	2	3
Shale with some ironstone	27	6
Sandstone	4	
Shale with some ironstone nodules and petrified sticks	19	6
Ironstone		3
Shale with bands of coal	1	9
Coal	1	8
Shale with ironstone bands	5	10
Shale with thin coal seams	7	
Shale, sandstone, and ironstone (cliff)	37	
Coal and coaly shale	1	
Shale with several bands of ironstone and ironstone nodules[2]	16	6
Shale with coaly streaks[2]	3	1
Ironstone nodules[2]		5
Shale with ironstone nodules[2]	3	
Clay ironstone	2	10
Gray fissile shale[2]	4	
Sandy shale somewhat massive	3	

Between the sandstone at the top of the foregoing section and the nearest and lowest outcrop of the Eska conglomerate on Wishbone Hill, about 0.6 mile to the southwest there are no exposures. About 1¾ miles west of this section, on the north slope of Wishbone Hill, sandstone, overlying shale and coal, outcrops below the lowest exposure of Eska conglomerate. The concealed stratigraphic interval between them is about 200 feet, and it appears most probable that the interval between the above section and the conglomerate is at least that much.

---

[1] This section is given in greater detail in section 37 (pp. 85-87).

[2] These beds yielded fossil leaves (lot 5897; see pp. 50-51).

Section in the Chickaloon formation on Matanuska River about one-eighth mile below Moose Creek.

	Ft.	In.
Shale	3	
Sandstone	5	
Thin interbedded shale and sandstone	2	4
Shale	15	
Sandstone	5	
Shale	18	
Coal		4
Carbonaceous shale	4	
Sandstone	23	
Carbonaceous shale	10	
Coal		6
Carbonaceous shale	5	
Sandstone		10
Shale [1]		3
Sandstone [1]	2	6
Shale [1]	1	
Sandstone [1]		6
Shale [1]		4
Sandstone [1]	7	6
Shale [1]	5	
Sandstone	4	6
Shale	6	
Sandstone	2	6
Shale	6	
Sandstone	2	6
Shale	15	
Sandstone	5	
Shale	10	
Sandstone	3	
Shale	15	
Sandstone	2	
Shale [2]	18	
Sandstone [2]	5	
Shale	20	
Shale and sandstone	30	
	253	7

FLORA AND FAUNA.

The fossils observed in these beds consist chiefly of leaves, which are very abundant though in general not well preserved except in the beds of iron carbonate. The following species have been identified by Arthur Hollick from material collected by Martin, Katz, and Chapin in 1910.

5892. North bank of Matanuska River, 4,200 feet below Moose Creek:
    Onoclea sensibilis arctica Heer=O. sensibilis fossilis Newb.
    Taxites validus Heer.

---

[1] Fossil leaves in lot 5892 collected at this horizon.

[2] Fossil leaves in lot 5901 collected at this horizon. See p. 50.

Sequoia langsdorfii (Brongt.) Heer.
Sequoia nordenskioldii Heer.
Poacites sp.
Quercus chamissoni Heer.
Quercus charpentieri Heer.
Quercus fraxinifolia Lesq.? (fragmentary).
Quercus juglandina Heer.
Quercus laharpi Gaud.
Dryophyllum sp.
Alnus kiefersteinii Heer.
Myrica langeana Heer.
Myrica acuminata Ung.? (fragmentary).
Juglans denticulata Heer.
Juglans heerii Ettingsh.
Ulmus sp.
Laurus primigenia Ung.? (fragmentary).
Cratægus sp.
Prunus serratula Heer.
Sapindus undulatus Heer.
Rhamnus gaudini Heer.
Pterospermites spectabilis Heer? (fragmentary).
Apeibopsis deloesi (Gaud.) Heer=Pterospermum deloesi Gaud.
Brasenia antiqua Newb.? (fragmentary).
Diospyros sp.
Viburnum antiquum (Newb.) Hollick=Tilia antiqua Newb. (Leaves and fruit; fide Ward, L. F., Bull. U. S. Geol. Survey No. 37, 1887, Pl. LI, figs. 2, 4-8.)
Viburnum asperum Newb.?
Viburnum nordenskioldii Heer.

Age, "Arctic Miocene" (Eocene).

5901. North bank of Matanuska River, 4,800 feet below Moose Creek:
Glyptostrobus ungeri Heer.
Salix reana Heer.
Quercus laharpi Gaud.
Quercus myrtilloides Ung.
Myrica langeana Heer.
Myrica vindobonensis Ettingsh.
Juglans bilinica Ung.
Juglans denticulata Heer.
Rhamnus eridani Ung.
Pterospermites dentatus Heer.
Fraxinus johnstrupi Heer.

Age, "Arctic Miocene" (Eocene).

5897. Eska Creek, west bank, elevation 1,100 feet:
Sequoia langsdorfii (Brongt.) Heer.
Sequoia nordenskioldii Heer.
Taxodium distichum miocenum Heer.
Taxites olrickii Heer.
Phragmites sp.
Poacites sp.
Cyperacites sp. } All fragmentary.
Typha sp.
Musophyllum sp.
Populus acerifolia Newb.

Populus arctica Heer.
Populus gaudini Fisch.-Oost.
Populus latior Al. Br.
Populus richardsoni Heer.
Salix longa Al. Br.
Corylus insignis Heer.
Alnus kiefersteini Heer?
Juglans acuminata Al. Br.
Juglans nigella Heer.
Ficus grönlandica Heer.
Planera ungeri Ettingsh.
Laurus primigenia Ung.
Cornus macrophylla Heer.
Pterospermites sp. A very large leaf about 2 feet long by 1½ feet broad.
Viburnum newberryanum Ward.
Viburnum nordenskioldii Heer.
Age, "Arctic Miocene" (Eocene).

5896. Young Creek, 0.6 mile northwest of Kings River:
Flabellaria florissanti Lesq. This lot consists of this one specimen.
Age, Tertiary, presumably Eocene.

5902. Shale at diorite contact at big bend of Young Creek, elevation 1,050 feet:
Populus zaddachi Heer? (fragmentary). Two specimens only in this lot.
Age, presumably "Arctic Miocene" (Eocene).

5904. Gulch on north side of Red Mountain, 4 miles N. 5° E. of mouth of Young Creek, elevation 3,500 feet:
Sequoia langsdorfii (Brongt.) Heer.
Populus gaudini Fisch.-Oost.
Age, presumably "Arctic Miocene" (Eocene).

5908. Young Creek, 0.55 mile north of 2,350-foot forks:
Sequoia langsdorfii (Brongt.) Heer.
Age, presumably "Arctic Miocene" (Eocene).

5899. "2½ miles northwest of U. S. L. M. No. 1; elevation 2,750 feet:"
Sequoia langsdorfii (Brongt.) Heer.
Populus arctica Heer.
Quercus olafseni Heer.
Pterospermites alternans Heer.
Age, "Arctic Miocene" (Eocene).

5895. "Talus slope at base of cliff, Kings River, east bank, at Coal Camp, 7 miles above mouth:"
Onoclea sensibilis arctica Heer=O. sensibilis fossilis Newb.
Taxodium occidentale Newb.
Populus arctica Heer.
Viburnum sp.
Age, "Arctic Miocene" (Eocene).

The following species have been identified by F. H. Knowlton from material collected by Paige and Knopf in 1906:

Moose Creek, 25 feet above 11-foot coal seam:
Sequoia langsdorfii (Brongt.) Heer.
Ficus? grönlandica? Heer.
Magnolia inglefeldi Heer.
Fragments of other dicotyledons.
Age, Kenai.

Kings Creek coal:
- Ficus? grönlandica Heer.
- Populus arctica? Heer.
- Rhamnus eridani Heer.
- Viburnum sp. cf. nordenskioldii Heer.

Age, apparently Kenai.

Chickaloon coal strata, Watson's camp:
- Sequoia langsdorfii (Brongt.) Heer.

Age, probably Kenai.

The species listed below were identified by F. H. Knowlton from material collected by Martin in 1905:

Chickaloon River, roof of coal bed in section 14 on page 80:
- Taxodium distichum miocenum (Brongt.) Heer.
- Salix varians Heer.
- Populus arctica Heer.
- Corylus macquarrii (Forbes) Heer.
- Juglans nigella Heer.

In addition to the plant remains, shells have been found in the thin ironstone (No. 17) in the section on page 44 of this report. Stanton says of two collections from this locality:

> 3316. Bend of Chickaloon River, half a mile above Watson's coal camp: This lot consists entirely of fresh-water gastropods, of which all but one specimen belong to a single species of Viviparus of a type that occurs in both the Upper Cretaceous and the Tertiary. The other specimen is a more slender form, too imperfect for generic determination. These fossils are apparently undescribed species—at least they are new to Alaska—and they do not fix the horizon more closely than is above indicated.
>
> 6698. Bend of Chickaloon River above big coal outcrop:
> Viviparus sp.
> Probably Eocene.

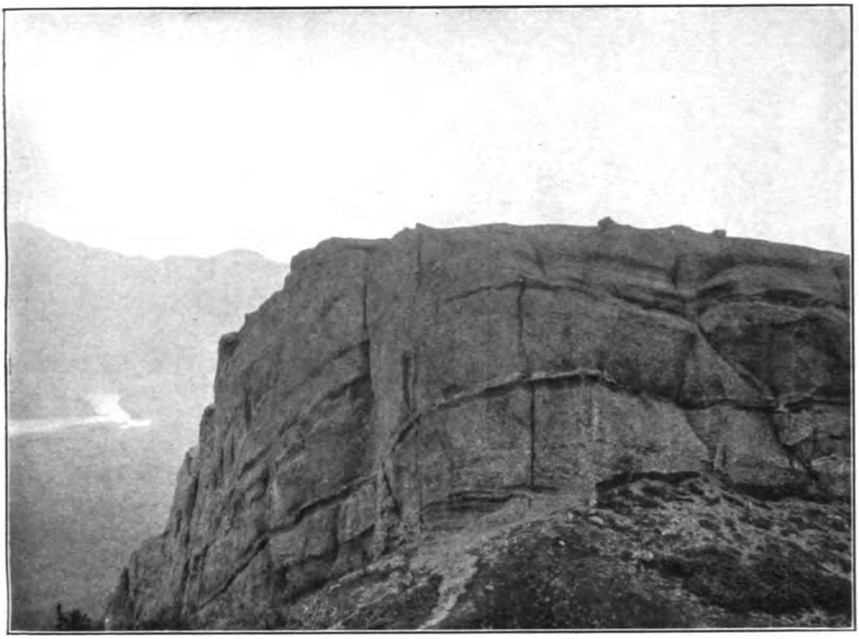
AGE AND CORRELATION.

The Chickaloon formation is shown by its flora to be certainly Tertiary and probably Eocene. It is the local equivalent of at least part of the Kenai formation of Cook Inlet and is the approximate equivalent of the Tertiary coal-bearing rocks which are present in many parts of Alaska.

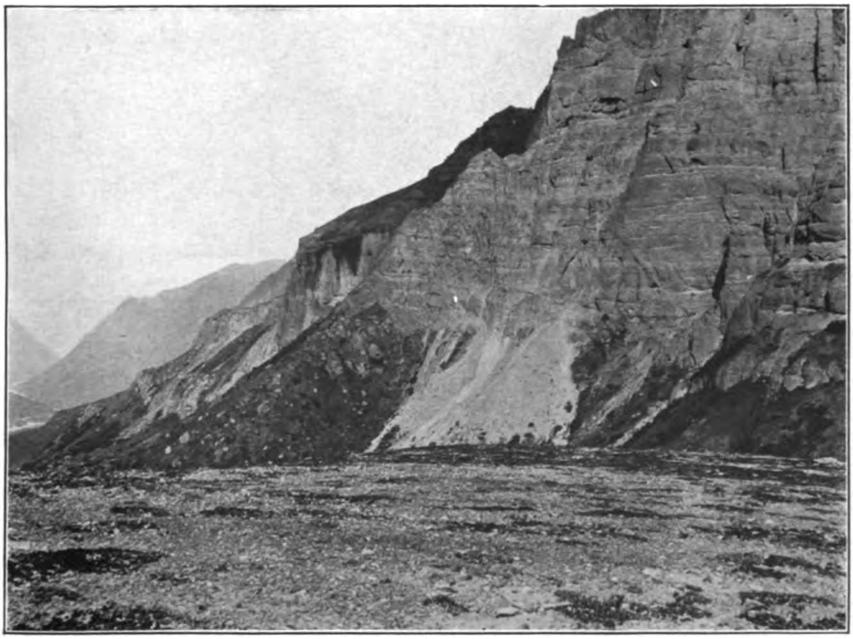
ESKA CONGLOMERATE.

AREAL DISTRIBUTION.

The Eska conglomerate occupies two areas. One extends westward from the valley of Eska Creek, from which the formation is named, to Moose Creek, outcropping in beautiful exposures in the cliffs of Wishbone Hill. The other is in Castle Mountain, extending eastward for 4 or 5 miles beyond Chickaloon River.



A. ESKA CONGLOMERATE ON WEST WALL OF VALLEY OF ESKA CREEK AT EAST END OF WISHBONE HILL.



B. ESKA CONGLOMERATE IN WEST END OF CASTLE MOUNTAIN.

LITHOLOGIC CHARACTER.

The Eska conglomerate is about 3,000 feet thick and consists of predominantly coarse conglomerate in massive plates interbedded with a very subordinate amount of coarse sandstone.

As exposed in Wishbone Hill the Eska conglomerate (see Pl. IX, *A*) consists of massive beds of conglomerate in thick plates with some intercalated lenses of coarse sandstones and a small amount of sandy shale. The bedding of the formation is marked only by the intercalated sandstones. The conglomerate is structureless save for a shingling which is only locally distinct. The sandstones are commonly cross-bedded and in some places strongly so. The dominant color of the formation is a light tawny red. Some of the sandstones, however, are whitish or gray. The rocks vary from coarse-grained sandstones or fine conglomerate in which the matrix preponderates to rocks crowded with pebbles up to 6 inches in diameter. Individual beds of conglomerate range in thickness from a few feet up to 75 feet. The sandstone beds are generally thin, although one 25 feet thick was noted. The pebbles range in size up to 8 inches, but most of them are between half an inch and 4 inches. They are well worn into a variety of shapes, of which subround, flattish, and elongate predominate. Some are subangular to shapeless, yet with well-worn corners and edges. The pebbles consist of porphyries of intermediate composition, which are the most abundant, granites, fine-grained igneous rocks, quartzites, and vein quartz. The matrix is sandy or arkosic. The conglomerate is all well indurated, yet it is more resistant where cemented along fractures, so that combs from a few inches to 1 or 1½ feet high and several inches thick stand up above the general surface.

Some obscure fossil sticks were found in sandstone near the summit of Wishbone Hill.

On Moose Creek about 1½ miles above the ford on the Chickaloon trail, the conglomerate immediately overlies the Chickaloon formation. It is composed chiefly of granite; the matrix is of granitic débris, and the bowlders are biotite granite and diorite. Among the smaller pebbles are also alaskite, gneiss, graywacke, metamorphic rocks, and quartz. The material is, for the most part, considerably under 1 foot in diameter, but there are a few large bowlders up to 4 feet in length. Lenses of arkosic sandstone occur within the conglomerate. The formation here is less indurated than on Wishbone Hill. The outcrop is crumbly and the bowlders are easily removed with a hammer.

On Castle Mountain the formation consists of conglomerate beds from 6 feet to at least 50 feet in thickness interbedded with strata of arkosic sandstone from 2 inches up to 30 or 40 feet thick. (See Pl. IX, *B*.) The beds of arkosic sandstone are fairly persistent, but some are lenticular. Small beds of finely laminated sandstones were seen. The basal beds of the conglomerate contain pebbles up to nearly 12 inches in diameter. About half of the pebbles are porphyries, acidic types predominating, and about one-third are black and dark-colored basic aphanitic igneous rock. The remainder are quartz, granite, diorite, other igneous rocks, greenstones, and various metamorphic rocks. The matrix consists of sandy material, with fine particles of igneous rocks, such as porphyries and traps, and dark minerals, such as hornblende and biotite. Locally the beds of sandstone grade into the conglomerate, but as a rule the contacts between them and the conglomerate are fairly definite. The sandstone itself is generally conglomeratic. It is essentially the same as the matrix of the conglomerate. The rocks in Castle Mountain are somewhat lighter colored than those in Wishbone Hill. This is due largely to the greater preponderance of porphyry pebbles which weather readily to a pale-green color.

AGE AND CORRELATION.

The Eska conglomerate rests upon the Chickaloon formation without observed unconformity. It is overlain unconformably by basaltic lavas and tuffs. No determinable fossils have been found in it, so the only conclusion that can be drawn regarding its age is that it is certainly Tertiary and is possibly the equivalent of the Miocene conglomerates which have been recognized at several points along the Pacific coast of Alaska.

BASALTIC LAVAS AND TUFFS.

The rocks forming the summit of Castle Mountain are basic volcanic rocks, most of which weather to a conspicuous red color. They comprise dense fine-grained black basalts and gray and reddish-gray amygdaloids and rocks of vesicular flow texture interbedded with tuffs and breccias of like material. There are some shale, sandstone, and conglomerate lenses (?) within the tuff and breccia beds. The lava beds are for the most part dense but in some places have columnar structure in their lower parts and are vesicular in their upper parts, being therefore clearly flows. The denser, more crystalline parts are composed of minute grains of feldspar and augite. The rock is similar to that described by Paige and Knopf[1] as an acidic olivine-free basalt composed of doleritic aggregates of labradorite (Ab_2An_3) and augite, with plagioclase as the dominant constituent. These basalts have very much the same composition as the gabbros and diabases that intrude the coal measures (pp. 63–67).

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, p. 30.

The section in the summit of Castle Mountain (see fig. 1) is as follows:

Section in summit of Castle Mountain.

	Feet.
Dense basalt	130
Tuffs, breccias, and vesicular lavas	170
Dense basalt, in part columnar at the bottom and vesicular at the top.	250
Tuffs, breccias, shale, sandstone, and conglomerate	90
Dense and amygdaloidal basalts	210
Unconformity.	
Eska conglomerate.	850

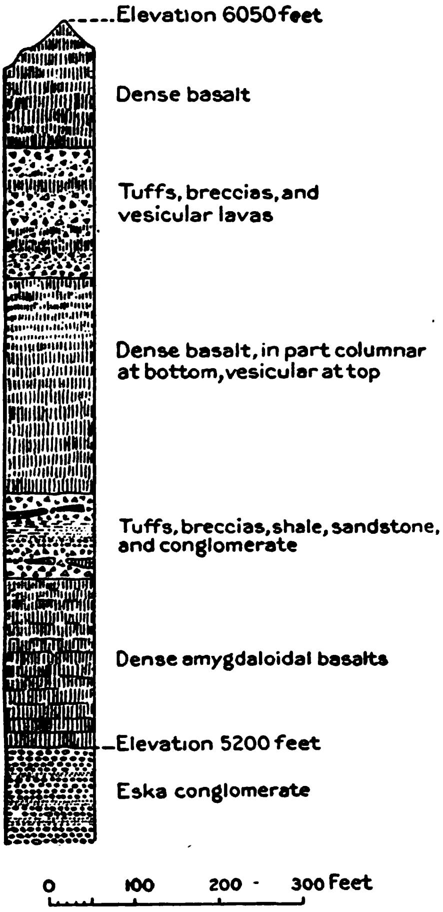

Elevation 6050 feet
Dense basalt
Tuffs, breccias, and vesicular lavas
Dense basalt, in part columnar at bottom, vesicular at top
Tuffs, breccias, shale, sandstone, and conglomerate
Dense amygdaloidal basalts
Elevation 5200 feet
Eska conglomerate
0
100
200
300 Feet

FIGURE 1.—Columnar section in summit of Castle Mountain.

The basalts lie upon an eroded but generally even surface which truncates the Eska conglomerate at a small angle (5° ±).

The base of the volcanic rocks is a dense, very fine grained basalt which apparently grades upward into a vesicular flow breccia. This is succeeded by beds of basalt, breccias, and tuffs with small amounts of sand and shale, all apparently strictly conformable and (on Castle Mountain at any rate) undeformed. Except the unconsolidated alluvial deposits, these basalts are the youngest rocks in the region. Their equivalence with the gabbros and diabases has been suggested by Paige and Knopf.[1]

TERTIARY INTRUSIVE ROCKS.

The igneous rocks which invade the Tertiary sediments of the region mapped on Plate V (in pocket) fall into three groups which are to some extent but not sharply differentiated by their areal distribution and lithology. The threefold grouping is as follows: (1) Diorite porphyries, including light-colored, usually porphyritic, fine-grained rocks of andesitic, diorite porphyry, and granite porphyry habit, which occur in the south-central portion of the region, especially in a large mass between Young Creek and Kings River, and in many smaller bodies in adjoining areas; (2) trachytic rocks, including greenish and brownish felsitic or porphyritic rocks which occur in two areas near the upper part of Young Creek; (3) diabases and gabbros, including bluish-gray to dark-green and black aphanitic, porphyritic, and coarsely crystalline diabases and gabbros, which are found abundantly east of Kings River but also sparingly throughout the other parts of the region.

---

[1] Op. cit., pp. 30-33.

DIORITE PORPHYRIES.

AREAL DISTRIBUTION.

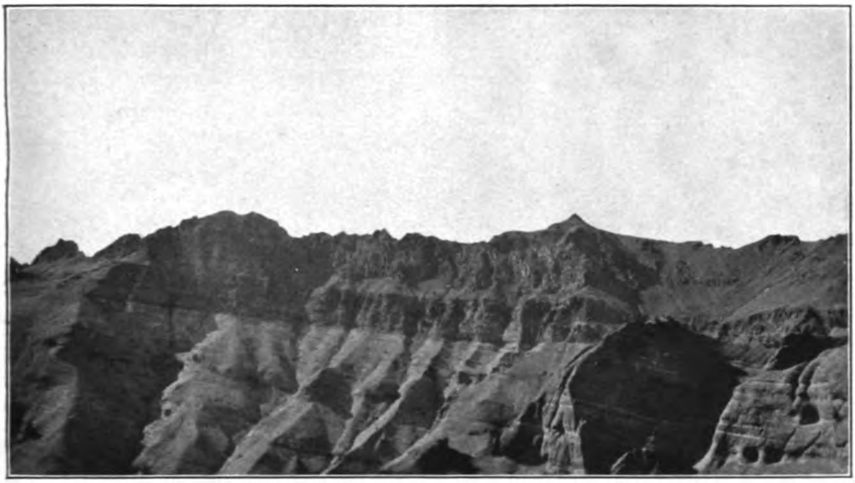
The diorite porphyries are in general restricted to an area extending eastward from the lower part of Young Creek to the lower part of Chickaloon River. Within this area they are the more abundant intrusive rocks present. Small masses of rocks of similar petrographic character were noted along the creeks north of Castle Mountain and along Carbon Creek, in areas in which the diabases and gabbros are the dominant intrusive rocks.

The larger intrusive masses recognized are situated as follows: In the hill between the lower course of Young Creek and Kings River and north of the lower course of Young Creek is an irregular area 5 miles long and, near its west end, 2 miles wide. Plate XI, *A*, shows the west end of this mass. In the hills west of the lower part of Chickaloon River and north of Matanuska River there are eight or more isolated exposures within an area of 2 or 3 square miles. In the top of the east bank of Kings River is a large sill which should probably be regarded as a prominent apophysis of the mass first noted above, and similarly the large dike and sills (see Pl. XI, *B*) in the south bank of Matanuska River belong with the second mass noted above.

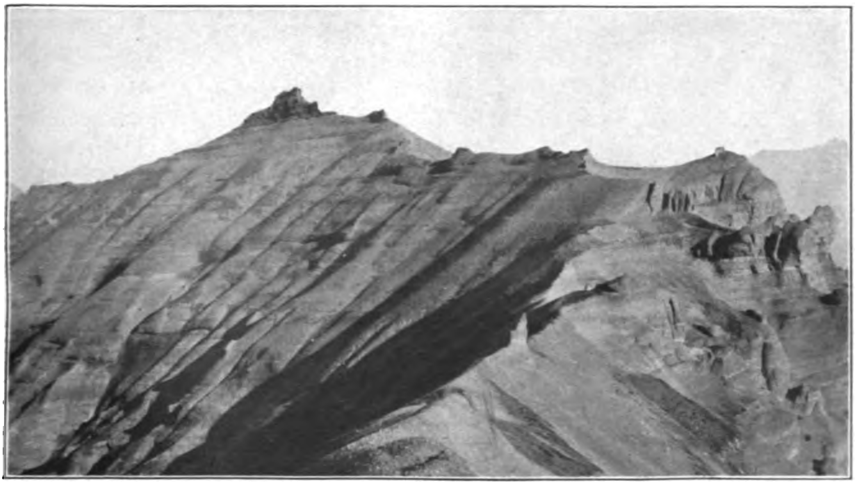
PETROGRAPHIC CHARACTER.

The rocks described under this heading are all light-colored porphyritic types ranging in composition from granite porphyries through soda syenite porphyries and diorite porphyries to augite andesites. The potash feldspar, orthoclase, is not an important constituent of any of these rocks and was not detected in most of them. They are also to some extent characterized by the presence of a colorless orthorhombic pyroxene and by a paucity of mica.

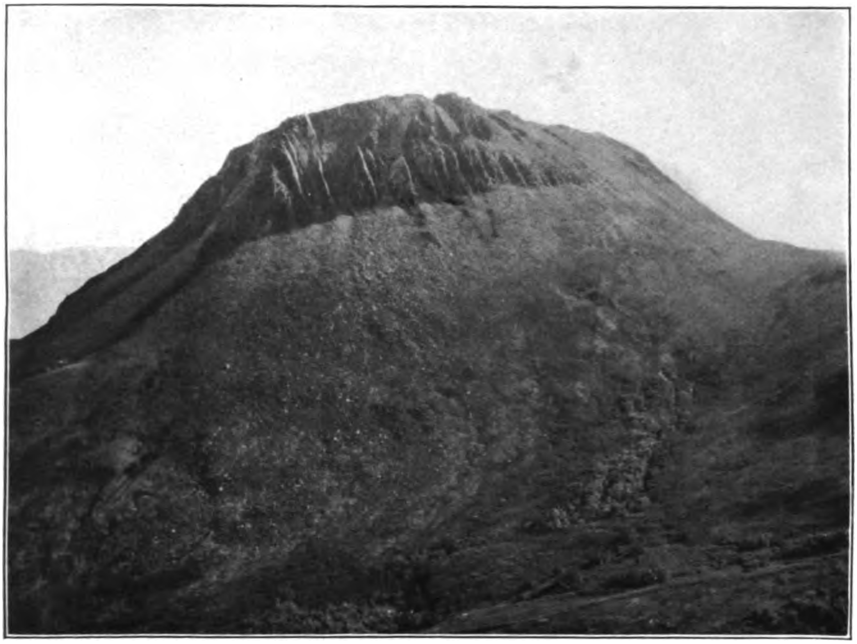
In the northern and western parts of the large mass which lies between Young Creek and Kings River, in the neighborhood of Young Creek (Pl. XI, *A*), there are light-gray porphyritic rocks in which the groundmass preponderates over the phenocrysts. The phenocrysts are chiefly small white or glassy feldspars; some rocks



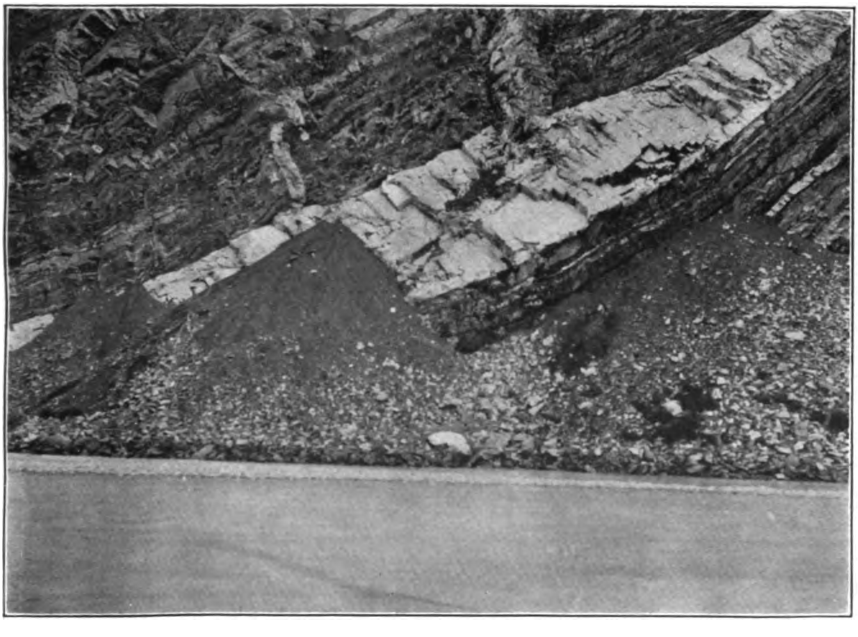
A. TERTIARY LAVAS UNCONFORMABLY OVERLYING ESKA CONGLOMERATE ON CASTLE MOUNTAIN.



B. ESKA CONGLOMERATE OVERLAIN BY SMALL CAP OF TERTIARY LAVA ON SOUTHEAST SPUR OF CASTLE MOUNTAIN.



A. PORPHYRY SILL (?) IN VALLEY OF YOUNG CREEK, OVERLYING CHICKALOON FORMATION.



B. PORPHYRY SILLS AND DIKES IN UPPER CRETACEOUS ROCKS ON SOUTH BANK OF MATANUSKA RIVER 2.7 MILES BELOW CHICKALOON RIVER.

also contain in considerable amount a dark ferromagnesian mineral, which is often found thoroughly weathered and then appears as small black spots. The gray groundmass is either fine grained or very fine grained to aphanitic. In some specimens there are vesicles partly or wholly filled with a pearly, pale leek-green mineral and some calcite. The weathered rocks are commonly yellowish or tawny, and some develop very uneven surfaces. The type specimen, an augite andesite, under the microscope shows feldspar and augite phenocrysts. The feldspar is chiefly labradorite-bytownite and less albite-oligoclase. Zonal growths in which the more acidic feldspars form the outer rims are common. The augite is in almost colorless large subhedral grains. There are also smaller grains of this mineral which approach in size the constituents of the groundmass. The groundmass contains the above-named feldspars and also some orthoclase (?), quartz in considerable amount, and colorless orthorhombic pyroxene in small columnar crystals. Iron oxides and apatite are abundant accessory constituents.

Near the northeastern border of the same intrusive mass are quartz diorite porphyries. These are moderately fine grained porphyritic holocrystalline rocks in which the phenocrysts about equal or preponderate over the groundmass. The phenocrysts, which are closely packed, are principally small rectangular white feldspars, between which are the darker phenocrysts and the minutely granular groundmass. The feldspars are plagioclase, zonally built, and ranging between andesine and labradorite. Other phenocrysts are biotite, colorless augite, and hornblende. The groundmass is quartz and feldspar. The quartz is abundant and partly idiomorphic in a paste of feldspars which, though obscure because fine and weathered, appear to be in part alkalic and in part a lime-soda feldspar. Magnetite and apatite are accessory constituents. Similar rocks in the central and southern parts of the mass have a little more coarsely crystalline groundmass and at several places are slightly different in composition. In one in which the dark phenocrysts are augite and hornblende, the feldspar is in part labradorite and in part alkalic feldspar. In another, whose dark phenocrysts are hornblende and biotite, the feldspar is about andesine in composition.

Some of the sills and dikes which intrude the coal measures and Upper Cretaceous rocks on the east and south of the large intrusive mass discussed above are acidic porphyries. These are in particular the large sill at the Kings River coal camp, the large sill and dikes on Matanuska River below Chickaloon River, and the light-colored intrusive rocks along and west of the lower part of Chickaloon River (Pl. XI, *B*). They are whitish or light-gray porphyritic rocks. The groundmass, which predominates over the phenocrysts, is either aphanitic or very finely crystalline. The phenocrysts are chiefly white or yellowish albite (or albite-oligoclase), idiomorphically developed. There are also biotite phenocrysts and in some specimens a few of quartz. The groundmass is acidic plagioclase and quartz, a small part of the quartz being graphically intergrown with feldspar which may be orthoclase. There is also a small amount of ferromagnesian mineral in the groundmass, but this is weathered beyond recognition in the sections examined. Iron oxide and apatite are accessory constituents. The rock at the Kings River coal camp has erroneously been called a monzonitic porphyry [1] and might better be given the qualitative name soda syenite porphyry.

A large number of dikes, mostly of small size and very fine texture, in the neighborhood of Kings River and the lower part of Chickaloon River, are probably related to the rocks described above. They are light-colored whitish, gray, or drab felsites or porphyries. A few are amygdular. The rock from one of these dikes, on the creek north of Castle Mountain, in the hand specimen appears to be a uniformly minutely granular and holocrystalline gray rock, but under the microscope it is seen to be porphyritic and possibly in part glassy. There is more of the groundmass than of the phenocrysts, which are only slightly larger than the individual grains of the groundmass. In places in the rock the texture of the groundmass is fluidal (pilotaxitic) by parallelism of the lath-shaped feldspars. The phenocrysts are albite and possibly also quartz. (The quartz noted may be secondary.) The groundmass is composed of intermeshed lath-shaped albite or oligoclase and also anhedral grains of clouded feldspar, quartz interstitial between the feldspars in rather subordinate amount, and abundant small crystals of magnetite and what appears to be chloritic material after ferromagnesian minerals, or may in part be devitrified glass.

A rock intrusive into the Tertiary sediments on Carbon Creek is a light-colored porphyry composed macroscopically of bunches of small white feldspar phenocrysts in a gray aphanitic groundmass. The groundmass is dominant over the phenocrysts. The feldspar phenocrysts are albite. The groundmass is composed of small intermeshed lath-shaped feldspars, probably acidic plagioclase, with very little quartz. There is also in the groundmass magnetite and considerable but obscure weathered ferromagnesian mineral or glass. Calcite and chlorite are abundant secondary minerals.

LOCAL RELATIONS.

The diorite porphyries and allied rocks are distributed through the region between Young Creek and Chickaloon River. They are in contact with Upper Cretaceous rocks and Tertiary coal measures.

---

[1] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, p. 16.

The andesite and diorite porphyry mass between Young Creek and Kings River is in its central portion a moderately coarse grained rock, peripherally a fine-grained holocrystalline porphyry which is in places miarolitic, and at the extreme margin in local narrow bands a porphyry with aphanitic groundmass. The intrusive relations of this rock are clearly shown at several points near its border.

On the west bank of Young Creek, about 1 mile above Kings River, Tertiary sediments directly overlie the igneous rock, which is here a felsite porphyry. The shales and sandstones are indurated by contact metamorphism (baked) to hard dense fine-grained rocks, and the intrusive is also dense and fine grained, so that the exact contact is not easily detected. A short distance down the creek from this locality about 30 feet of shale overlies the igneous rock, the surface of which is about parallel to the bedding of the shales. (See fig. 2.) Near the contact the igneous rock is dense and aphanitic, but at a little distance it becomes porphyritic. In the lower foot the shale is very completely indurated and in the succeeding 3 feet is baked to a hard dense rock. About 2 miles above the mouth of Young Creek, entirely within the intrusive mass, there is a small area of Tertiary shales and sandstones. Through a distance of 400 feet along the creek these rocks lie above the intrusive, which is very fine grained, porphyritic, and slightly vesicular at the contact. There are some 30 feet of shales and sandy shale which are nearly horizontal. They are baked through a thickness of at least 25 feet and have been changed from soft shales to very firm and hard lighter-colored rocks.

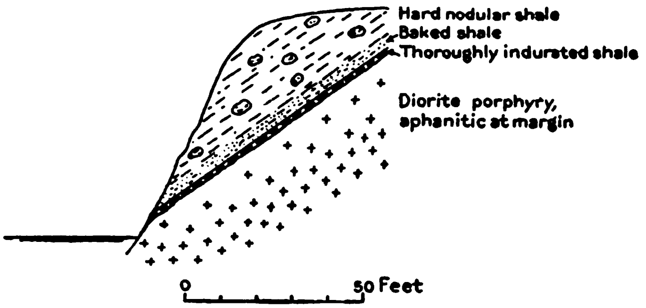

Hard nodular shale
Baked shale
Thoroughly indurated shale
Diorite porphyry, aphanitic at margin
0
50 Feet

FIGURE 2.—Section in cliff on Young Creek, showing relation of diorite porphyry to Tertiary sediments.

Tertiary shales of the Chickaloon formation are in contact with the diorite porphyry about three-fourths of a mile up the first northerly tributary of Young Creek (Pl. XI, *A*). These shales are indurated. They lie along the creek topographically below the diorite porphyry in the ridges, so that the diorite appears to overlie the shales. This, furthermore, appears to be the general relation of the Upper Cretaceous as well as the Tertiary sediments which are exposed on the north side of the diorite porphyry north of Young Creek.

Along the fourth mile of Young Creek above the mouth the contact of the diorite porphyry with the Tertiary sediments is in the south bank. Here the igneous and sedimentary rocks are faulted against each other. There is at some places a fault breccia zone, 100 feet or more wide, affecting both rocks. The intrusive porphyry is much saussuritized, shattered, and veined with calcite. The masses of shale and other sediments included in the brecciated zone are also shattered and veined, but not so extensively as the diorite porphyry. (See fig. 3.) At several places on this part of the creek, along the general position of the contact, outcrops of both igneous and sedimentary rock, slickensided or shattered, indicate movements which must have been subsequent to the intrusion, for the evidence elsewhere is conclusive that the diorite porphyry is intrusive into the Tertiary sediments. There may be faults of considerable magnitude that essentially determine the present surface outline of the rock masses, or the faults may merely represent slight compensatory movements during the cooling of the intrusive mass.

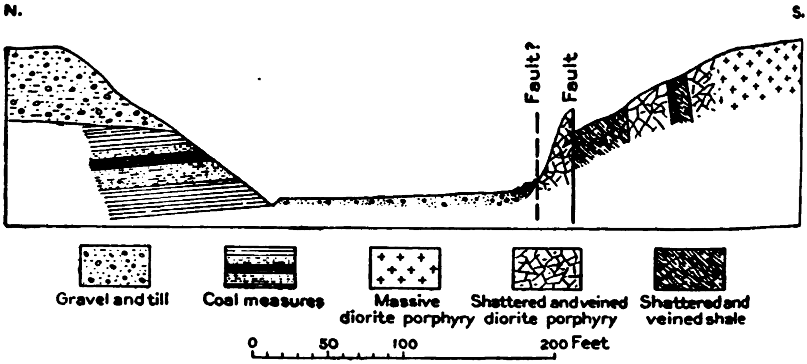


FIGURE 3.—Section on Young Creek showing relation of diorite porphyry to Tertiary sediments.

About a mile north-northwest of Kings River Bridge the same diorite porphyry mass whose relations to the Tertiary sediments are discussed above is in contact with Upper Cretaceous sandstones and shales. The contact appears to be intrusive because of the markedly porphyritic border phase of the igneous rock and because the sandstones nearest the porphyry are indurated and altered. The sandstones and shales outcrop below and dip toward cliffs of diorite porphyry. The conditions thus suggest that the igneous rock overlies the sediments and that it is here the edge of a sill-like or laccolithic mass.

The above-described contact relations of the diorite porphyry mass are along its western and northern borders. The rock extends southeastward to the flats of Kings River, where its limits are obscured by the alluvial deposits of that stream.

The many small masses of porphyries petrographically allied to the diorite porphyries are clearly intrusive into Upper Cretaceous rocks and Tertiary coal measures (Chickaloon formation). Structurally they are sills and dikes which are for the most part of regular outline. Except the very large sills, they have little or no metamorphic effect on the rocks they invade. At Kings River coal camp one sill which is 60 feet thick has visibly indurated the shales beneath it through a distance of less than a foot.

On Chickaloon River at several localities the light-colored porphyry sills parallel the folded beds of the Chickaloon formation, as indicated in figure 4. The beds seem to be too sharply and complexly deformed to permit an invading magma to follow the folds. It is more probable that, had the intrusion been subsequent to the folding, the intrusive, rather than insinuating itself for considerable distances along single much-distorted bedding planes, would have cut across beds along joints and minor faults, which are numerous. It would appear, therefore, that the intrusion of the diorite porphyry and allied rocks preceded at least a considerable part of the deformation of the Tertiary coal measures (Chickaloon formation). This is further suggested by the above-discussed fault, which marks part of the north boundary of the large diorite porphyry mass and which may be of considerable magnitude.

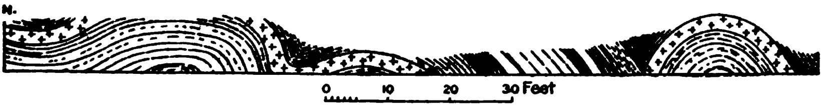


FIGURE 4.—Folded beds of the Chickaloon formation and sill.

TRACHYTIC ROCKS.

AREAL DISTRIBUTION.

The trachytic rocks were seen only in the upper part of the valley of Young Creek, where they occur in two large masses. One of these occupies what is called Red Mountain and the other is about a mile northeast of it.

PETROGRAPHIC CHARACTER.

The type rocks from Red Mountain are either greenish-gray or brown porphyries in which feldspar and mica phenocrysts only are visible in a felsitic base. The feldspar phenocrysts are long and slender. Under the microscope the several specimens look very much alike. They are trachytic (fluidal-textured) porphyries, the groundmass strongly predominating over the phenocrysts. The phenocrysts are plagioclase and biotite. The former ranges from albite to oligoclase, and some pieces have inclusions of quartz and glass. Most of those examined under the microscope are very long, slender laths and appear to have been broken and in part replaced by quartz and to have undergone other alteration. Other more compactly shaped feldspar phenocrysts also showed slight crushing effects. The groundmass is composed of lath-shaped feldspars (acidic plagioclase and possibly also orthoclase), biotite in subhedral grains, abundant small idiomorphic crystals of magnetite, and a little glass. Interstitial primary quartz is present in accessory amounts only. On the east of Young Creek, opposite Red Mountain, the rocks of this group are greenish-gray felsites with a few sparse phenocrysts of feldspar. They are fine-grained and locally slightly trachytic rocks which consist of acidic plagioclase (and orthoclase?) phenocrysts and also considerably altered ferromagnesian phenocrysts in a groundmass made up chiefly of acidic plagioclase and quartz. The plagioclase of the groundmass is lath shaped, for the most part irregularly intermeshed but locally in rudely parallel arrangement. The groundmass contains also some biotite or pyroxene, very much decomposed, and a little devitrified glass. Minute crystals of magnetite are abundant, and apatite is a fairly constant accessory. One of these rocks is a yellowish-green (weathered) porphyritic felsite which contains minute microscopic red garnets. These are about the only phenocrysts visible without the microscope. This rock contains considerable quartz in the groundmass, but, save for this and the garnets, is very like the rock just described. Some of the garnets have macroscopically sharp crystal outlines, but those seen in thin section are irregularly bounded. They contain numerous inclusions of quartz and other minerals, and are surrounded by calcite of secondary origin. There is considerable calcite and other secondary material throughout the rock.

The felsitic and porphyritic rocks of this group, taken as a whole, are more weathered than the dioritic rocks of the first group. One of the trachytic rocks, furthermore, shows slight effects of crushing, a phenomenon not developed in the dioritic rocks.

LOCAL RELATIONS.

The trachytic rocks were found in Red Mountain and the hills northeast of it on the opposite side of Young Creek. Their main masses have no visible contacts with other rocks except that some dikes of similar character cut the surrounding Upper Cretaceous beds and Tertiary coal measures. In Red Mountain the igneous rocks of this group occupy the summit and lie at greater elevation than the neighboring rocks. Coal within less than 50 feet is not visibly different from coal exposed at long distances from the trachytic rocks. There is here a suggestion that the igneous rocks overlie the sediments. A dike of small size similar in character to the Red

Mountain rock cuts folded Tertiary sediments in the saddle west of Red Mountain and with them is faulted (?) against Upper Cretaceous shales and sandstones.

Rocks similar to those of Red Mountain occurring east of Young Creek are surrounded partly by Tertiary and partly by Upper Cretaceous sediments, but the relations are obscure except where a large dike cuts the Upper Cretaceous beds.

DIABASE AND GABBRO.

AREAL DISTRIBUTION.

The more basic igneous masses occur chiefly within an area beginning at the knoll east of Kings River and at the southwestern base of Castle Mountain and extending eastward beyond the region covered by the detailed map (Pl. V, in pocket). The northern boundary of this area is along the south base of Castle Mountain, and the area is defined on the southwest by a line from the knoll east of Kings River southeast across Matanuska River. No intrusives other than those discussed under this heading were noted within this area. Twenty masses were mapped within the area described above, and there are a great many smaller ones. The larger masses are those which outcrop in the knolls north and northwest of Chickaloon, along Chickaloon River, and in the hills east of Chickaloon between Boulder Creek and Matanuska River. Eight of these have a surficial extent of one-fourth to one square mile or more. Smaller dikes and sills of diabase were seen outside of the general area described above, along the gorge of Kings River, on the creek tributary to Kings River north of Castle Mountain, in the basin of Young Creek, on Wishbone Hill, and on Arkose Ridge.

PETROGRAPHIC CHARACTER.

All the rocks are very similar in constitution, although they present considerable differences in appearance. There were seen in the region a few small dikes of amygdular basaltic rock of dark color in which, under the microscope, only labradorite is determinable in a microgranular, much weathered groundmass. Blue-gray or greenish-gray fine-grained sills are very numerous. These are usually ophitic in texture and composed of labradorite, augite, and iron oxide. They are as a rule considerably weathered, calcite, chlorite, and limonite, being developed from the pyroxene. The gabbroic rocks are for the most part coarse dark-green to black rocks composed of labradorite, common augite, magnetite, and ilmenite. They are slightly ophitic in texture, particularly in the finer-grained varieties which form the borders of large masses or make up the whole of narrower dikes and sills. A number of these are quartz diabases having a notable amount of quartz interstitial between the feldspars. In other respects these quartz diabases are not different from the normal diabases of the region. In some places lighter-colored bands or dikelike masses, usually of small size, traverse the coarse gabbros, from which they differ slightly in texture and composition. One fine-grained variety contains, besides the usual constituents, zonally developed plagioclases which vary from bytownite to albite, the interior zones being the more calcic. This rock contains also primary quartz. Other varieties are coarse grained, composed chiefly of plagioclase and augite, the former being dominant. Bands of this rock a few inches thick traverse normal gabbros. Under the microscope there seems to be no difference between them other than in size of grain, which changes abruptly. Olivine gabbros with but little olivine, and in other respects like the usual rocks of the region, were noted at two localities.

LOCAL RELATIONS.

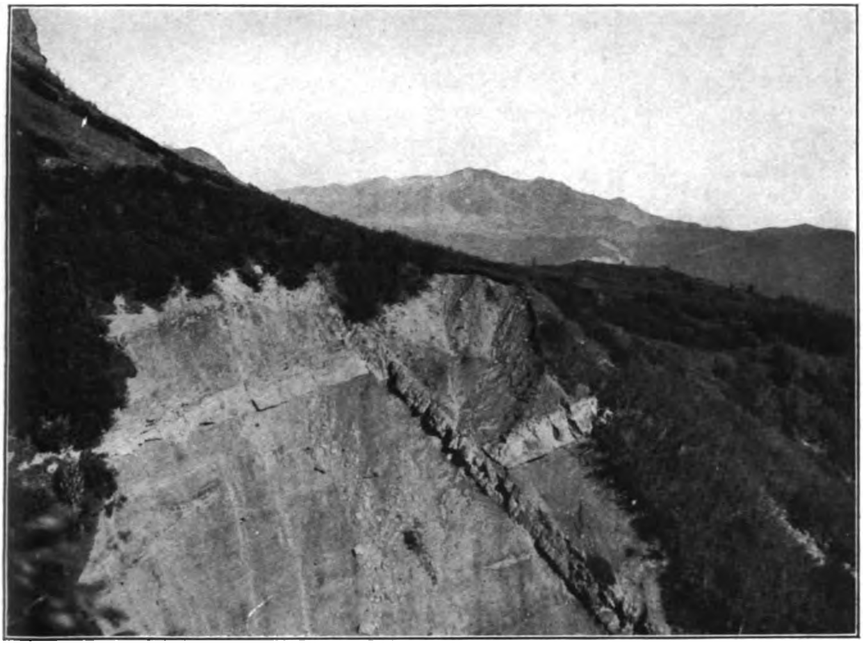
The rocks of this group are developed chiefly in the eastern part of the region considered, but are also found sparingly in the western part. With only one or possibly two exceptions, so far as known, they are all intrusive into the Tertiary arkoses and coal measures (Chickaloon formation). The exceptions are a small gabbro dike which cuts Upper Cretaceous shales in a gulch about 3¼ miles north of the mouth of Young Creek and a gabbroic rock on the south side of Matanuska River 2¾ miles below Carbon Creek, which is near but not in visible contact with Upper Cretaceous beds. In the latter occurrence both the petrographic character and the structural relations of the rock are uncertain.

Small basaltic and amygdular dikes and sills occur in Tertiary beds exposed in Arkose Ridge. About 5½ miles N. 10° W. of the mouth of Moose Creek an amygdaloidal basalt, intruded approximately parallel to the bedding of the arkose above it, is cut off by a fault. Two miles west of this are some very small basaltic dikes and sills in shaly members of the same series.

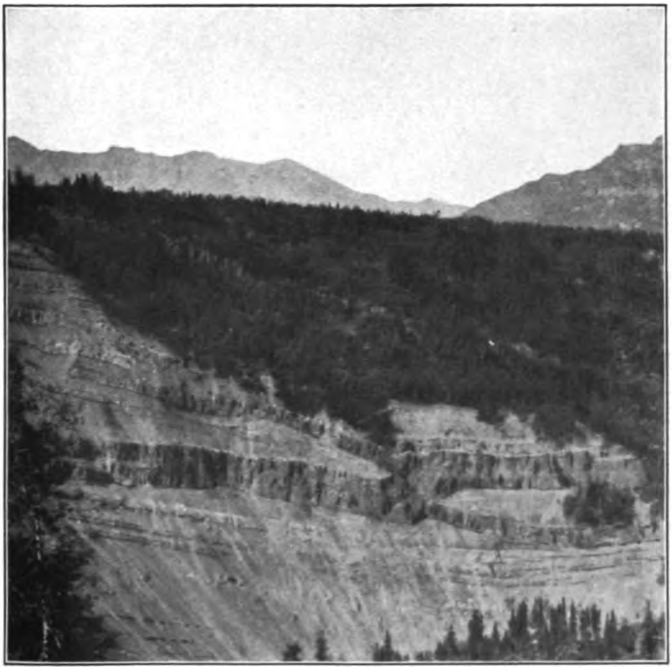
On the north side of Wishbone Hill, in the sandstone below the conglomerate, there is a small intrusive gabbro mass.

In the Young Creek region two diabase dikes were seen on Division Creek. One 2 miles N. 75° W. of the mouth of Young Creek is 25 feet thick. It cuts coal-measure beds about parallel to their strike but with opposite dip.

Gabbro cuts the coal measures on Young Creek about 3 miles up from the mouth. The coal at the contact is coked, and the other sediments are indurated. The gabbro is exposed for 150 feet. It is very fine grained and bluish at the intrusive margin and fine grained but distinctly gabbroid elsewhere. Except at the intrusive contact



A. DIABASE DIKE ON FAULT IN CHICKALOON FORMATION AT BASE OF CASTLE MOUNTAIN.



B. DIABASE DIKES AND SILLS IN CHICKALOON FORMATION ON NORTH BANK OF BOULDER CREEK.

noted its relations are obscured by several displacements. The locality is along the faulted contact of coal measures and diorite porphyry, and it seems probable, though not at all certain, that at one point where gabbro and diorite porphyry appear to be contiguous the former intrudes the latter. The faults which cut the gabbro appear to be of minor importance and are about normal to the main coal measures and diorite porphyry fault contact.

There are a number of diabase intrusions in the Chickaloon formation along Kings River. These are in masses from 1 or 2 feet up to 12 feet thick and of considerable extent which are parallel to or very closely follow bedding planes. They have no noticeable metamorphic effect on any beds except where they come into contact with coal. A large sill at the Kings River coal camp has coked the lower half of a 16-foot coal bed immediately above it.

East of Kings River the gabbros and diabases are abundantly developed in the Tertiary coal measures. The very numerous smaller bodies, which are fine grained and ophitic, are usually sills—that is, they are concordant, or approximately so, with the beds in which they are seen. A few dikes were noted. Four or five small dikes on Matanuska River about a mile below Chickaloon River are anastomosing dikes roughly parallel to the dip of the shales which they intrude. At a locality near Chickaloon small dikes have broken through thin beds of sediments between a number of closely spaced sills. (See fig. 5.) A diabase dike 6 to 10 feet thick is intruded on a fault near the south base of Castle Mountain. (See Pl. XII, *A*.)

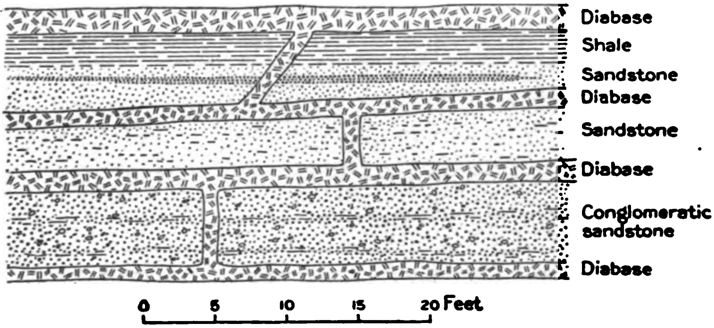


FIGURE 5.—Diabase sills and dikes in the Chickaloon formation near Chickaloon.

A number of diabase intrusions on Boulder Creek cut the Tertiary beds at a very low angle and in part are parallel to the bedding. A large mass, 20 feet or more thick, through most of its length parallels closely the bedding but at one point is offset as if following a slight displacement of the inclosing beds. At that point there are two branch dikes, one on either side, which appear to follow the joint or fault that has caused the offset in the large dike. (See Pl. XII, *B*.) In the vicinity of this complex dike are several others of apparently less extent and very nearly parallel to the bedding.

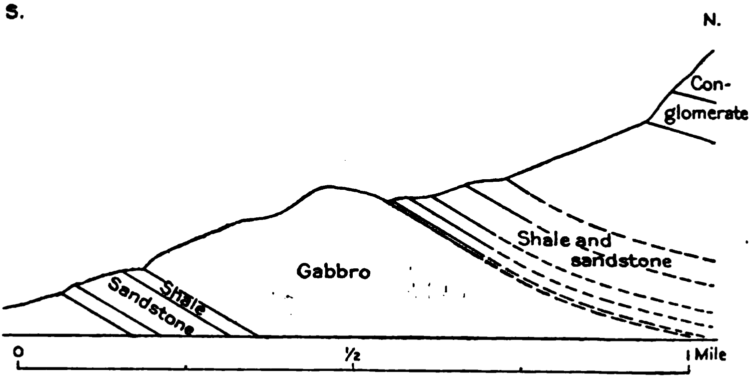


FIGURE 6.—Section at south base of Castle Mountain, showing relation of gabbro to Tertiary sediments.

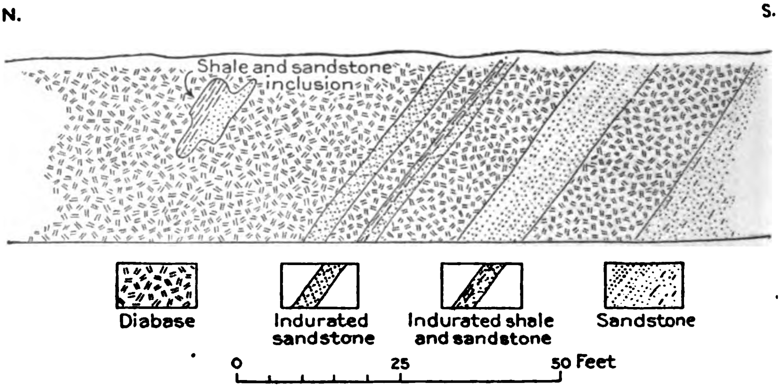


FIGURE 7.—Section along cliff on west bank of Chickaloon River, showing relation of diabase sills to Chickaloon formation.

The larger masses of basic intrusive rock, the coarse crystalline gabbro, are to a considerable extent also injected along bedding planes. They are for the most part either thick sill-like bodies or flat laccolithic bodies like those shown in figures 6, 7, and 8. Such

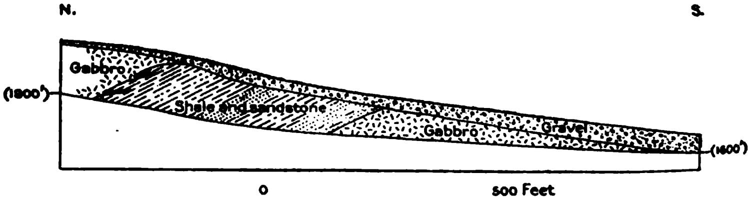


FIGURE 8.—Section in bank of creek 1¾ miles northwest of Chickaloon, showing relation of gabbro to Chickaloon formation.

are most of the gabbros south of Castle Mountain and along Chickaloon River. Some, however, break across bedding as is indicated in figure 9.

The gabbro masses east of Chickaloon River and between Boulder Creek and Matanuska River are distributed in an arc about a central mass of gabbro. This arc parallels the outline of the central mass. Sandstone was observed at one locality outcropping at the outer base of the gabbro cliffs and apparently underlying them. At another locality what is probably the same gabbro injects overlying shales. (See fig. 10.) The central mass of gabbro which makes the hill 2 miles east of Chickaloon is sheeted by a platy parting, and along planes parallel to the parting are narrow bands of coarser light-colored gabbro. These partings are very probably cooling joints developed parallel to the surface of the igneous mass. By their attitude they support the suggestion gained from the distribution of the gabbro that there are here two heavy gabbro sheets which are slightly dished and pitch southwest.

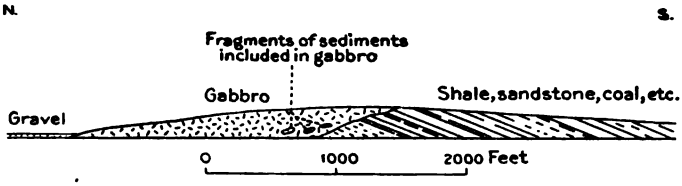

N.
S.
Fragments of sediments included in gabbro
Gabbro
Shale, sandstone, coal, etc.
Gravel
0
1000
2000 Feet

FIGURE 9.—Section in cliff on east bank of Chickaloon River, showing relation of gabbro to Chickaloon formation.

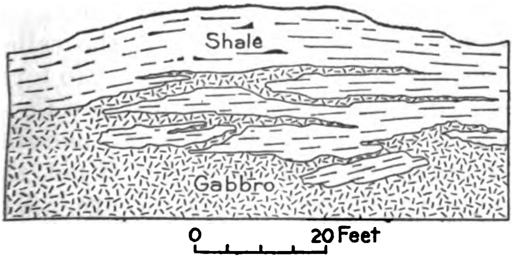


FIGURE 10.—Gabbro injected into shale, south of Boulder Creek.

The gabbros and diabases were nowhere seen to be folded like the coal-measure beds they invade and they are faulted only locally and to an unimportant extent. They are probably younger than the principal and important deformation which affected the coal measures and therefore are younger than the diorite porphyries and allied rocks.

QUATERNARY DEPOSITS.

The unconsolidated Quaternary deposits of the Matanuska Valley include morainic deposits, terrace gravels, and the alluvium on the flood plains of the existing streams. These deposits cover the greater part of the surface, except on the cliffs and steep mountain slopes and the higher mountain summits. They are represented on the geologic map only in their better development—that is, where they constitute the most characteristic feature of the areal geology.

MORAINIC DEPOSITS.

Glacial moraine material is present in at least a thin film over nearly the entire area here described. It is better developed toward the west end of the Matanuska Valley than at corresponding altitudes farther east. The gentler slopes of the valley below elevations which rise from about 2,000 feet in the valley of Moose Creek to about 3,000 feet in the valley of the Chickaloon River are practically all covered with moraines except where recent stream erosion has removed these deposits or where the slopes are too steep to retain unconsolidated material. The glacial deposits are much thicker west of Young Creek than east of it, the reason for this difference lying in the facts that the deposits were formed by a large glacier which formerly occupied the entire length of the valley and that the region below Young Creek was one in which the glacier received only smaller tributary ice streams and consequently deployed over the lowlands, being therefore less actively erosive than above. The abundance of glacial débris in this western part of the region indicates that for a long time the advance of the ice was so balanced by melting that the foot of the glacier was held in this neighborhood, hence the large accumulations. This former Matanuska Glacier probably filled the entire valley from side to side, its margins coinciding approximately with the present positions of the linear mountain fronts which border the valley. It probably extended westward beyond the present limit of the valley and very likely joined other large glaciers of similar character to form a greater ice mass which occupied at least a part of what is now Cook Inlet. Gravel ridges which were regarded as bits of lateral moraine and which probably mark a resting stage of the glacier, if not the extreme lateral position, were seen at the base of Arkose Ridge, north of Moose Creek, at an elevation of about 2,200 feet. These ridges are considered as marking the position of the edge of the ice during its largest extension of any considerable duration. The distribution of the morainic material and the evidence of glacial erosion indicate that at this stage the margin of the ice rose steeply eastward, being at an elevation of about 3,200 feet between Eska and Granite creeks, and at least 3,500 feet in the vicinity of Castle Mountain. East of Kings River evidence concerning the precise position of the edge of the Matanuska Glacier is not at hand, the problem being complicated by the fact that it is impossible to differentiate between material left and erosion forms caused by the glacier occupying the main valley and by the small local glaciers which occupied tributary valleys and which may or may not have been confluent with the main ice mass. It is certain that many smaller glaciers existed and probably every small valley in the high mountains was occupied by one.

The mountain masses adjacent to the Matanuska Valley were probably during the period of maximum glaciation a nest of multitudes of glaciers among and between which peaks and ridges and possibly broader areas of bare rock protruded. There is, however, no evidence that the whole region was swept over by glaciers of anything like the continental type.

Glacial deposits are beautifully developed in the low hills along the lower courses of Moose and Eska creeks and in the area under 800 feet in elevation which lies between them. Exposures are few except where the larger streams are at present vigorously cutting, but the character of the topography is that of typical glacial deposits formed at a period of partial stagnation of the ice. These deposits are somewhat obscured along the present drainage lines by terraces and terrace gravels which have been cut into and built over them. Back from the present drainage lines they exist in essentially unmodified form. East of Granite Creek deposits of this type are less well developed, the glacial deposits being thinner. They are, however, to be seen at the lower elevations in the region between Kings and Chickaloon rivers.

There is abundant physiographic evidence of intense glacial erosion in the valleys of Kings and Chickaloon rivers and farther east. The porphyry hills on Young Creek show clearly the effect of glacial scour. The morainic mantle is here thin; the hilltops and in many places the lower slopes of the hills are swept bare, having only a few glacial pebbles and bowlders scattered over them. The rock surfaces show typical glacial rounding and gouging and many of the rougher slopes and cliffs were produced by plucking, a mode of erosion facilitated by the parallel jointing of the diorite.

TERRACE GRAVELS.

The terrace gravels are of two kinds. The most broadly developed occur at low altitudes, not having been seen above about 1,100 feet. These are found on well-developed cut and built gravel benches which rise in a series of steps along the river. In the valley of Moose Creek they were noted at elevations of about 400 to 1,000 feet, the best-developed benches being at approximately 400, 450, 500, 670, 825, and 1,000 feet. On Eska Creek there are well-developed benches at about 940 and 1,000 feet. Between Eska and Granite creeks benches were noted at elevations of 660, 680, 720, 740, 850, 950, and 1,150 feet. In the valley of Kings River there are many well-developed terraces of which the highest is at about 1,200 feet. On Chickaloon River the best-developed terraces are at about 1,000 feet. The position of some of the terraces observed in the different parts of the area is indicated on the geologic map (Pl. V, in pocket) and profiles of the terraced banks of Moose Creek and of Kings River are given in figure 11. The character of the material in which these terraces are developed is shown in Plate XIII.

The character of these deposits is well shown in the north bank of Matanuska River 0.9 mile above Moose Creek. At this point the bluff, 200 feet high, is composed of interbedded gravel and silt. The silt is yellow and rather coarse. The gravel occurs in bands, lenses, and pockets irregularly distributed. It is predominantly of rather fine grain (less than 2-inch pebbles), although parts are coarse, with abundant 6-inch cobbles and bowlders up to 2 feet in diameter. The material is all stratified and is in general well sorted. The pebbles represent a great variety of material. Granitic rocks predominate, but sandstone, shale, and a variety of fine-grained basic rocks are abundant. Much of the coarser gravel occupies channels in the sands. This gravel deposit is shown in Plate XIII, *B*.

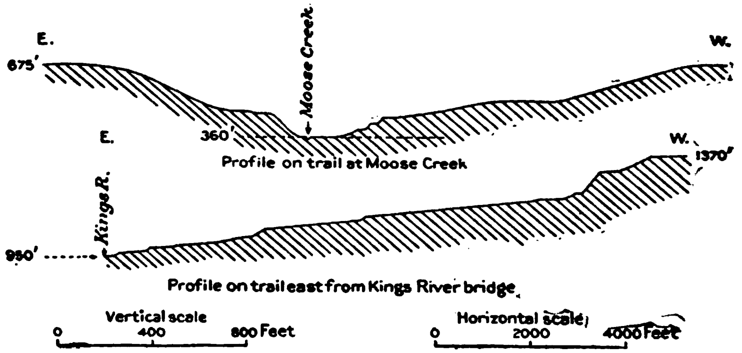
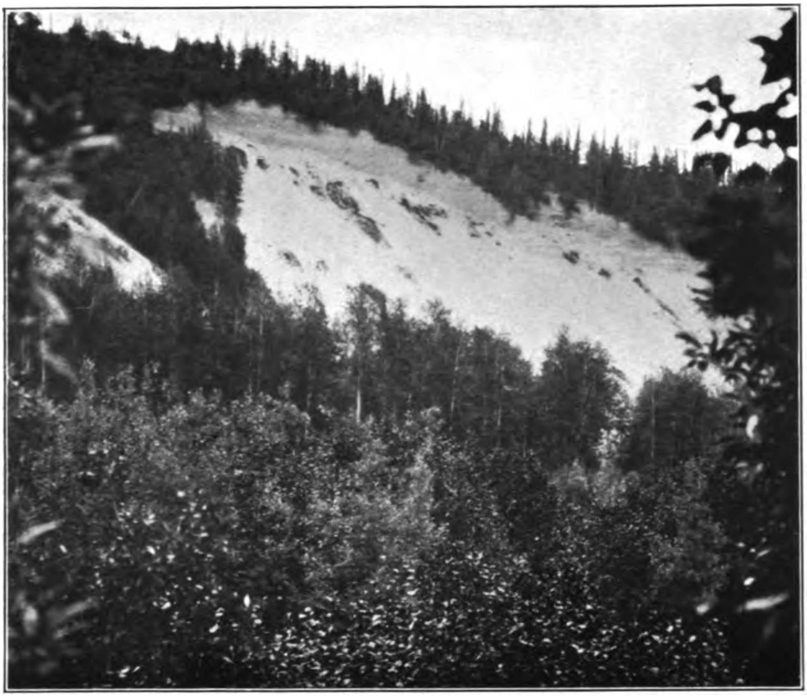


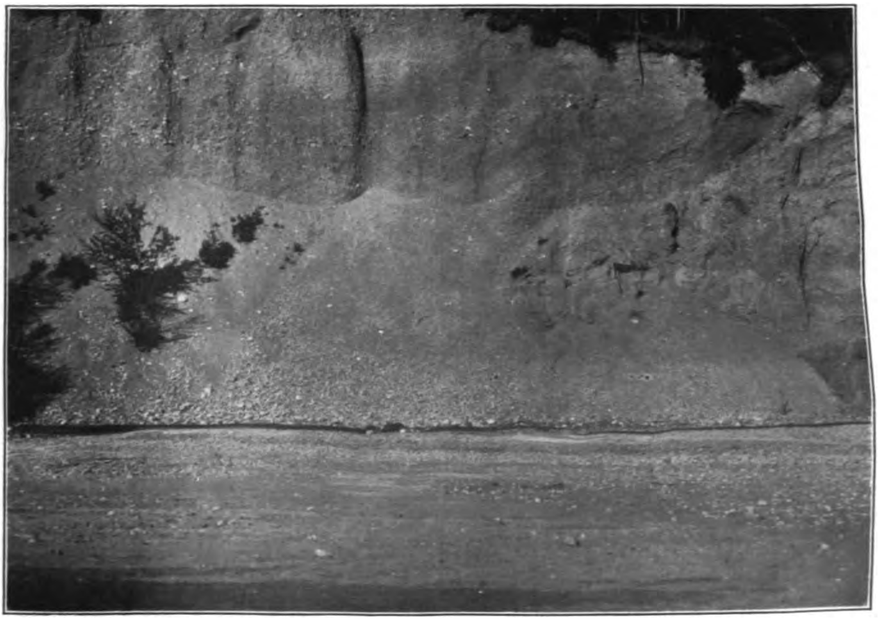
FIGURE 11.—Diagram of terraces on Moose Creek and on Kings River.

Gravel-covered terraces of somewhat different type were seen at higher elevations. Where the valley of Moose Creek comes out from the high mountains there are gravel benches up to an elevation of about 2,200 feet. Similar benches are seen at about the same altitude where Granite Creek emerges from the mountains. On the west side of Kings River, at a point about 2 miles north of the bridge, well-developed benches were observed at an elevation of 1,800 feet. They occur opposite the coal camp at an elevation of about 1,500 feet and on the east side of the creek at an elevation of about 1,700 feet. Broad gravel-covered flats at an elevation of about 1,600 feet were seen on both sides of Chickaloon River about a mile above Boulder Creek.

The significant fact in the distribution of these high-level terraces is that they are apparently restricted to the vicinity of the tributaries



A. STRATIFIED GRAVELS ON EAST BANK OF KINGS RIVER NEAR LOWER BRIDGE.



B. GRAVEL CLIFFS ON NORTH BANK OF MATANUSKA RIVER 1 MILE ABOVE MOOSE CREEK.

of the Matanuska and were not seen at other points. It is believed that they were laid down in the ponded waters of these tributaries at times when the main Matanuska Glacier stood across the mouths of the tributary valleys.

ALLUVIUM.

Alluvial deposits are well developed on all the larger streams and on such of the smaller ones as do not have steep grade over continuous exposures of rock. The flats and gravel bars along the whole course of the Matanuska constitute one of the striking features of the geology of this region. The high degree of the development of these deposits is caused by the fact that the Matanuska is a heavily overloaded glacial stream whose flow, owing to the intermittent and varying supply, is very irregular. The Matanuska and its tributaries freeze every winter and tend to seek new courses when the spring thaws come. The run-off during the early summer months is much greater than at any other time of the year. The streams have their sources in large part at the ends of glaciers and are consequently loaded with detritus from the very start. They flow for the most part over unconsolidated deposits and have steep grades. They are consequently choked with sediment at all times, and whenever the water falls they begin to aggrade their beds.

The gulches traversing the lower and gentler slopes between Moose Creek and the ridge north of it show evidence of an apparently unusual recent stream activity. The streams, which are small even in the last half of June, when much snow remains on their headwaters and melting is rapid, occupy each a trench in a wide gravel and bowlder-strewn course through the brush and timber. This course is typically 100 feet wide, and in cross section its surface is flat or slightly convex. The stream occupies a shallow, usually indefinite, and random channel. The sides of the course are strewn with bowlders 5 to 10 feet in diameter, lodged among living and recently fallen trees. The first impression is that within three or four years on all the small streams there have been great floods that have cut wide courses through the timber, in which vegetation has not yet regained a foothold. It is, however, difficult to understand how any ordinary flood could handle material of such size and handle it as vigorously as is testified by the abraded, torn, and broken trees. If at the time of the floods the streams were frozen, or if their channels were filled with snow, as they usually are until late in the spring, these bowlders might have slid along on the steeply sloping ice or snow. The phenomena might well be the product of the regular early spring melting floods, the large bowlders being moved each year a little at a time. Similar conditions were observed on the tributaries of Eska and Granite creeks, on the creek north of the west end of Castle Mountain, and on many other creeks throughout the valley.

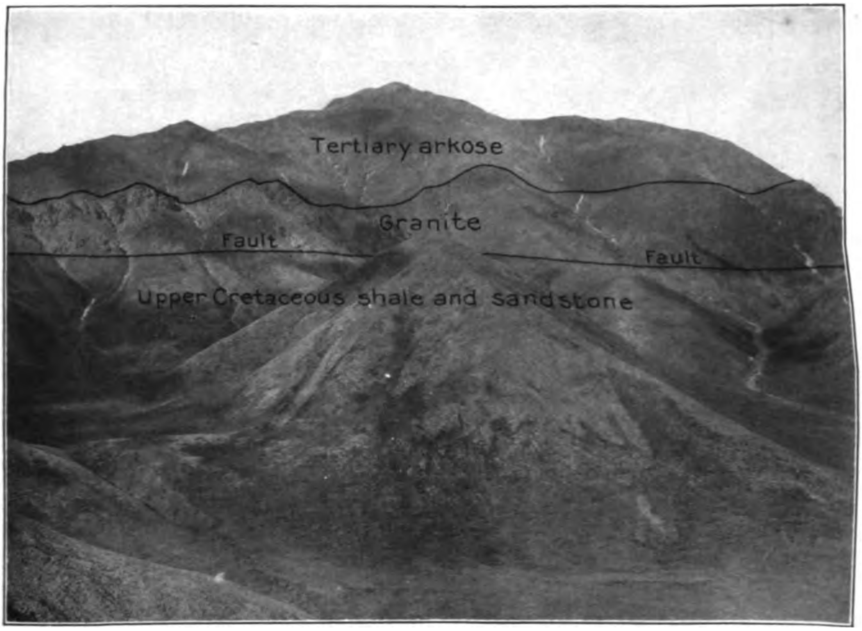
Many such accumulations of débris were seen on the lower courses of small streams heading in mountain gulches. The deposits are at and below the points where the gulches leave the very steep slopes and enter upon the comparatively flat gravel-covered floors of their master valleys. The débris appears not to have been distributed in typical alluvial fans, as by torrential streams, but rather as if it had been borne in a mass and suddenly dumped. It is therefore suggested that the hypothesis stated above might be modified so as to make snow-slides or avalanches rather than melting floods the agents which carried the débris out of the high gulches. According to either explanation the bowlder accumulations are a result of the spring and early summer thaws.

STRUCTURE.

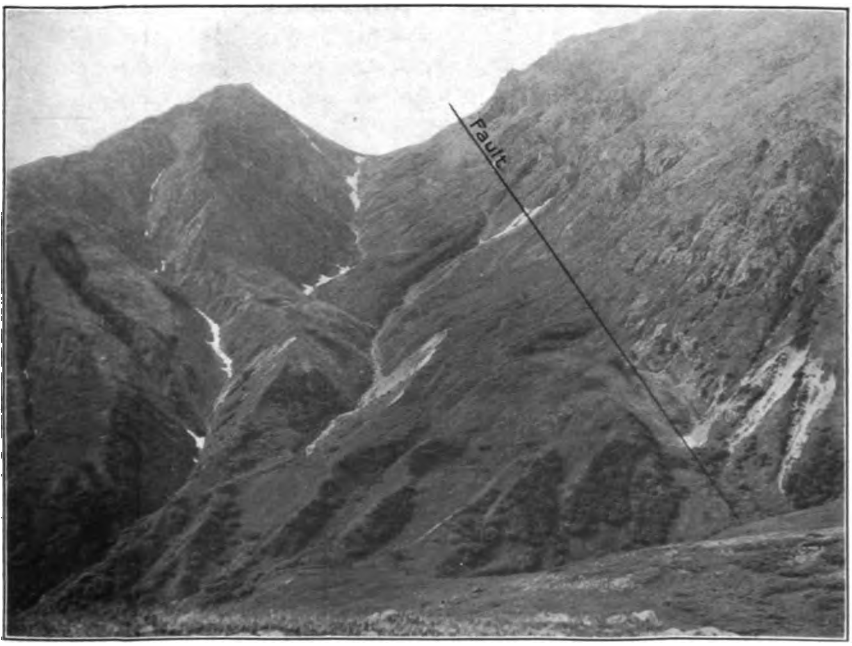
The dominant structural features of the Matanuska Valley bear a very close relation to the physiography and to the areal distribution of the different kinds of rock. The south front of the Talkeetna Mountains, which terminate on a remarkably straight line parallel to the general course of the Matanuska and about 5 or 6 miles north of it, is determined by a great fault or zone of faulting which was followed from one end to the other of the area mapped in detail and which probably extends for indeterminate distances farther in either direction. It is believed that this fault marks approximately the course of Little Susitna River below its point of emergence from the mountains, and it possibly extends east of Chickaloon River along the upper course of Boulder Creek.

The mountain and larger hills which interrupt the lowland area south of the great fault are occasioned by their structural features. Castle Mountain and Wishbone Hill are synclinal masses. The hills in the Young Creek region are partly monoclinal blocks of Upper Cretaceous sediments and partly intrusive bodies.

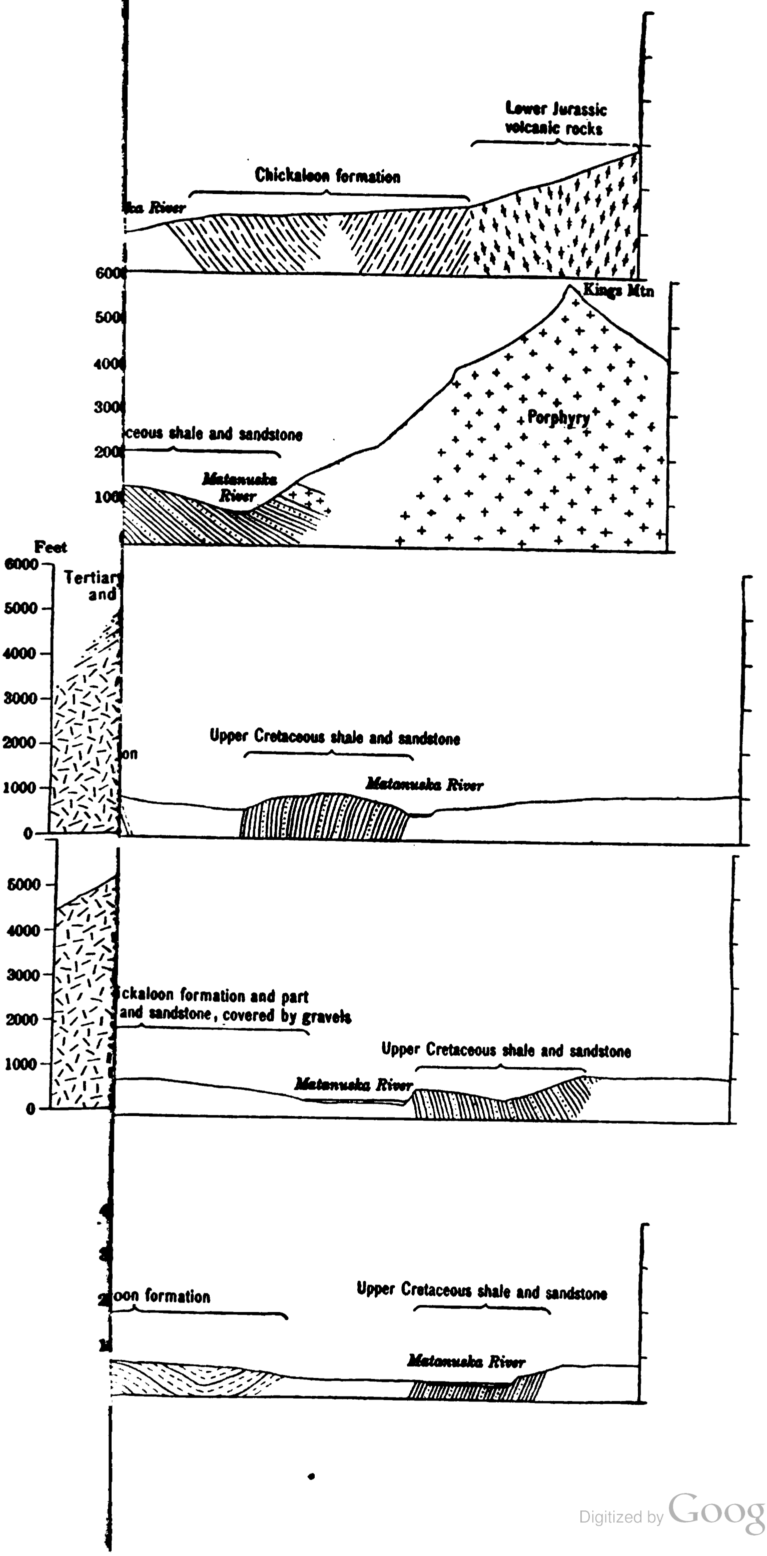
The best exposures of the great fault were seen on the headwaters of Young Creek and in the hills north of Castle Mountain. In the former locality two approximately parallel fault planes were observed at a distance of about half a mile apart. On the northern of these the granite is thrust upon the Tertiary arkose. At the southern fault the granite, which is overlain by the Tertiary arkose, is faulted against the Upper Cretaceous rocks (Pl. XVI, section H–H′; Pl. XIV, *A* and *B*). The observed relations at this point are shown in Plate XVI, section H–H′, and Plate VII, *B* (p. 28). The fault where observed north of Castle Mountain brings both the granite and the Lower Jurassic volcanic rocks into contact with the Tertiary rocks



A. FAULT ON NORTH EDGE OF MATANUSKA VALLEY NEAR HEADWATERS OF YOUNG CREEK.



B. FAULT BETWEEN GRANITE (AT RIGHT) AND UPPER CRETACEOUS ROCKS (AT LEFT), ON CREEK THAT ENTERS KINGS RIVER FROM THE WEST 1¼ MILES ABOVE COAL CAMP.


Lower Jurassic volcanic rocks
Chickaloon formation
ka River
600
500
400
300
200
100
Kings Mtn
Porphyry
ceous shale and sandstone
Matanuska River
Feet
6000
5000
4000
3000
2000
1000
0
Tertiar
and
on
Upper Cretaceous shale and sandstone
Matanuska River
5000
4000
3000
2000
1000
0
ckaloon formation and part
and sandstone, covered by gravels
Upper Cretaceous shale and sandstone
Matanuska River
oon formation
Upper Cretaceous shale and sandstone
Matanuska River

(Pl. XV, section B–B′; Pl. XVI, section G–G′) and farther east has brought the basal conglomerates of the Tertiary into contact with the much higher Eska conglomerate (Pl. XV, section A–A′; Pl. XVI, section F–F′). The faulting throughout this zone is believed to be everywhere of reversed character, the fault planes dipping steeply to the northwest. The rocks north of the fault zone and close to it are in many places closely folded and in some places overturned, so that the axial planes dip to the north. The character of this overturned folding is shown in limestone beds represented on sections through Castle Mountain (Pl. XVI, section G–G′) and also in the overturned anticline in the Tertiary rocks shown in Plate XVI, section H–H′, and Plate VII, *B* (p. 28).

At many places the rocks on each side of the major fault plane are much fractured and crushed through a zone several hundred feet wide. The granite has as a rule been severely shattered for a considerable distance from the contact. It is very much altered and epidote, chlorite, and other minerals are developed. To a slight extent it has received a gneissoid texture by the crushing into parallelism of some of its constituent minerals.

The granitic rocks and the Tertiary arkoses are in contact along the western half of the northern limits of the area. The relations are of two kinds. Around Moose Creek there is no good evidence that they are other than those of normal deposition of the beds of the arkose series upon the granites and gneissic rocks. The basement rocks at this locality include, besides some folded and sheared, thoroughly gneissic and schistose rocks which are intruded by granitic rocks, also granites of gneissoid habit which have been subjected to crushing forces. The more metamorphosed rocks are dominant near the contact; the merely gneissoid granites are more abundant away from the contact. This relation might be interpreted to mean that deformation had been largely confined to and accentuated along the contact of Tertiary rocks and granite. However, it seems certain that the metamorphic facies were developed and were injected by the granitic rocks prior to the arkose epoch and that the resulting complex became the basement for the deposition of the arkose. Because of the facts that the sedimentary series is arkosic and that the granitic rocks, gneisses, and schists are represented by pebbles in the conglomeratic members of the arkose series it is fairly certain that the arkose was derived from and deposited upon the granites, gneisses, and other rocks. The cataclastically developed gneissoid textures, on the other hand, seem to be significant of post-Tertiary deformation, for the granites are similarly gneissoid at other localities where they are faulted against the Tertiary sediments.

Between the arkose and the granite on Eska Creek there is a severely crushed fault zone which shows many planes of movement, some in the granites and some in the sedimentary rocks. Masses of both rocks are mixed in irregular alternation within the zone. The arkose is greatly indurated and resembles the igneous rock. The granite is badly fractured and contains seams of epidote, quartz, and calcite. On the west of Granite Creek the relations are as on Eska Creek. This fault zone extends eastward from Eska Creek across Sheep Valley. There the granite not only occurs above and north of parts of the arkose, being faulted against it, as just described, but also lies below the arkose, as on Moose Creek, being the basement upon which it was deposited.

The approximately linear front of the northern edge of the Chugach Mountains, which lies about parallel to the front of the Talkeetna Mountains, suggests that the south wall of the Matanuska Valley, like its north wall, is determined by faulting. Unfortunately not enough observations were made south of the river to establish this point fully, and the linear character of the mountain front may be due entirely to truncation of the spurs by glacial erosion.

The general character of the structure of the valley is indicated in the sections on Plate XV. The sedimentary rocks have been strongly folded, so that steep dips and complex structures are present throughout most of the area. At some places there is a continued uniform dip for considerable distances, but it is not known whether this condition means simple monoclinal structure or a repetition of parallel fault blocks. At other places there are frequent reversals of dip, but this again may be either simple folding or more complex faulting. In each of these cases the lack of definite knowledge concerning the type of structure is due to the absence of recognized characteristic strata from whose distribution the structural details could be inferred.

In two areas within the field the type of structure is known with a fair degree of certainty. These areas are those occupied by the conglomerate in the vicinity of Castle Mountain and of Wishbone Hill. The clearly defined contacts of the conglomerate with the adjacent rocks, as well as the various individual beds of conglomerate, here make it possible to determine the actual structural details.

The west end of Castle Mountain (see section B–B′, Pl. XV) is a monoclinal block having a dip of about 6° to 20° NE. The east end. as is shown in section A–A′, Plate XV, is a syncline having a broad southern limb on which the dips range from 10° to 20° N. and a narrow, sharply upturned northern limb with dips of 60° to 90°. Possibly the northern limb of this syncline is cut off in the western part of the mountain by a fault, or, on the other hand, the structure may be dominantly monoclinal with local upturning of the strata along the fault in the eastern part of the mountain but not in the western part.

Wishbone Hill is in general structurally similar to Castle Mountain. The east end, as is shown in section D–D′, Plate XV, is a syncline pitching sharply toward the west. The west end is likewise synclinal, but the northern limb of the syncline has been cut by a fault in the west end of the hill and in the valley of Moose Creek, as is shown in section E–E′, Plate XV, so that the conglomerate mass, as exposed on Moose Creek, shows dominant northward dip and would, but for a few exposures showing gentle southward dip, appear to be a monoclinal block.

The points of dissimilarity between Castle Mountain and Wishbone Hill are that in Castle Mountain the entire northern edge is bounded by a fault which has brought the arkosic rocks beneath the coal into contact with the conglomerate above the coal, while in Wishbone Hill the fault is possibly absent at the east end of the hill, so that the coal-bearing rocks encircle the end of the conglomerate mass, and at the west end of the hill the fault is not of sufficient magnitude to bring more than the coal-bearing rocks into contact with the conglomerate. The syncline at the east end of Castle Mountain pitches toward the east; that at the east end of Wishbone Hill pitches toward the west.

In the area south of the great fault between Granite Creek and Young Creek, occupied by Upper Cretaceous shales and sandstones, the structure probably departs only slightly from monoclinal. The dips are southeast, fluctuating between 30° and 60°. On the east and north of this area the structures are more complex in the vicinity of the great fault and of the numerous large intrusive masses.

Where the Upper Cretaceous rocks are exposed along Matanuska River they are broken by a number of faults and are considerably more crumpled and shattered than at other localities. Unfortunately the cliffs are inaccessible for close study, so that the true character of the deformation and its structural significance are not known. It would seem, however, that the course of the river is along some structurally important line. The upper part of Kings River also may be on such a line, for it marks an eastern limit of the Upper Cretaceous rocks and the western limit of both the Lower Jurassic volcanic rocks and of one area of the Chickaloon formation.

MINERAL RESOURCES.

COAL.

AREAL DISTRIBUTION.

The coal of the Matanuska Valley occurs in several isolated fields, only part of which are included in the area here described. Three of these coal areas lie partly within the area described in this report. Of these the Chickaloon field is situated mostly in the lower part of the valley of Chickaloon River but extends west as far as Kings River, south across the Matanuska into the valley of Coal Creek, and possibly east beyond the Chickaloon Valley. The Eska-Moose field, which is second in area and importance, extends from the valley of Eska Creek west as far as Moose Creek and possibly into the gravel-covered area beyond it. The Young Creek field is intermediate in geographic position between the Chickaloon and Eska-Moose fields, being situated in the upper part of the valley of Young (Little Kings) Creek.

The areal extent of the assemblage of rocks which carry the coal is indicated on Plates V and XVIII (in pocket). The areas indicated as coal-bearing are those which may carry coal as distinguished from the areas (represented by other patterns on the map) which are known not to carry coal. The areas of the "coal-bearing rocks" can not be assumed to be underlain wholly by beds of coal of workable character and thickness. Moreover, parts of these areas may have no coal under them. The lack of knowledge as to the exact stratigraphic position of the coal beds, the uncertainty as to what stratigraphic parts of the "coal-bearing rocks" are represented by the several surface outcrops, and the concealment of the rocks by gravels over broad areas make the precise areal distribution of the coal a problem which can be solved only by drilling or other underground exploration.

The areas of the tracts which it is believed may contain workable coal are indicated in the subjoined tables. The first of these tables shows the areas known to be occupied by the "coal-bearing rocks," as defined above, and by the conglomerates and other beds which overlie them. The second table shows the areas which may also be underlain by these rocks but in which, because of concealment by gravels or of other lack of definite information, there is a possibility that other formations may be present. These estimates are provisional and are subject to modification, perhaps considerable, when the region is more thoroughly prospected.

Areas of supposed coal-bearing rocks.

	Square miles.
Valleys of Chickaloon and Kings rivers	44
South of Matanuska River between Kings Mountain and eastern edge of area shown on Plate V (in pocket)	8
Valley of Young Creek	3
Valleys of Moose and Eska creeks	19
	74

Areas of possible extensions of the supposed coal-bearing rocks.

	Square miles.
Lower parts of valleys of Kings and Granite creeks	8
Valleys of Moose and Eska creeks	16
	24

STRATIGRAPHIC OCCURRENCE.

The coal beds of the part of the Matanuska Valley here under discussion are all known to be of Tertiary age and to agree approximately in general stratigraphic position with the coal of the Kenai formation on Cook Inlet. They all occur within the Chickaloon formation, which is the middle local division of the Tertiary rocks as grouped in this report. Their exact position within this formation has not been determined, but they seem to be in general distributed throughout the greater part of its thickness. Nothing definite is known as to the persistence of individual beds or of groups of beds.

DESCRIPTION OF BEDS.

The following pages contain measured sections of all the coal beds which were accessible either in natural exposures or in prospect openings or tunnels. The location of the sections is shown by the numbers, which correspond to those on Plate XVIII (in pocket). No attempt has been made to correlate the beds, as the complex structure, the abrupt changes in thickness, and the fact that most of the beds have not been traced from point to point make correlation impossible. The sections are arranged in order from east to west:

Sections of coal beds in lower Matanuska Valley.

1. South bank of Matanuska River 3 miles above the mouth of Chickaloon River.

Gray shale.	Ft.	in.
Coal		6
Shale		1
Coal (samples 6, 7, p. 90)	7	
Gray shale with ironstone bands	42	
Coal		6
Shale	1	6
Coal	5	
Gray shale	7	
Coal		6
Shale	4	6
Coal		8
Shale		1
Coal	5	8

Soft gray shale.

Strike N. 63° E., dip 44° SE.

2. East bank of Coal Creek 4,100 feet from mouth.

Soft dark shale.	Ft.	in.
Coal (samples 8, 9, p. 90)	2	2
Parting.		
Coal (samples 8, 9, p. 90)	1	5
Sandstone		2–6
Coal (samples 8, 9, p. 90)	1	

Soft shale.

Strike N. 89° W., dip 70° S.

3. East bank of Coal Creek 500 feet upstream from preceding section.

[Shown in Pl. XIX, *B*, p. 92.]

	Ft.	in.
Intrusive sheet and coke	12	
Coke	5	
Intrusive sheet with coke	14	
Shale	10	
Coal (samples 10, 11, p. 90)	6	3
Shale		2
Coal (samples 10, 11, p. 90)		6
Shale		11
Coal		9

Soft shale floor.

Strike N. 89° W., dip 70° S.

4. West bank of Coal Creek 6,645 feet from mouth, at elevation 1,030 feet.

Gray shale.	Ft.
Coal	6
Shale	3
Coal (shaly)	11

Carbonaceous shale.

Sections of coal beds in lower Matanuska Valley—Continued.

5. West bank of Coal Creek 6,865 feet from mouth.

	Ft.	in.
Gray shale.		
Coal		8
Shale		0–2
Coal	1	9
Shale with some coal	1	7
Gray shale.		

Strike N. 77° E., dip 60° NW.

6. East bank of Coal Creek 7,700 feet from mouth, at elevation 1,055 feet.

	Ft.	in.
Gray shale.		
Coal	4	7
Shale		2
Coal		3
Shale		½
Coal		8
Shale		1
Coal		7
Shale		2
Coal	1	7
Shale		1
Coal		11
Carbonaceous shale	2	5
Shale and coal altered by dike		6

Strike N. 67° E., dip 65° NW.

7. Bend of Chickaloon River half a mile above Chickaloon.

[Shown in Pl. XIX, *A*, p. 92.]

	Ft.	in.
Black shale.		
Coal		7
Coal, bony		4
Shale		5
Coal		6
Shale, black	1	6
Coal	2	
Concealed	1	

7. Bend of Chickaloon River half a mile above Chickaloon—Continued.

	Ft.	in.
Shale	3	6
Coal		7
Shale		8
Coal		10
Shale		6
Coal	2	3
Shale and sandstone (horse)	10	
Coal		6
Shale with coal stringers	1	
Coal		10
Shale		4
Coal		2
Shale	1	
Coal		6
Shale		1
Coal	4	4
Shale.		

8. Tunnel A, Chickaloon.

	Ft.	in.
Coal	1	2
Bone and coal		9
Coal	14	8
Shale	12	
Coal		8
Bone and shale		5
Coal		8
Shale	12	
Coal	3	
Shale and sandstone	77	

Strike N. 43° W., dip 65°.

9. Tunnel A, Chickaloon.

	Ft.	in.
Coal in face		11
Shale	5	2
Coal	1	4
Bony coal	1	

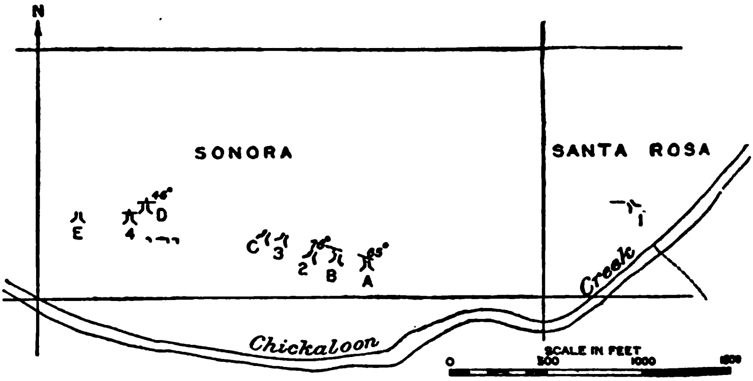


FIGURE 12.—Sketch showing location of Chickaloon tunnels.

Sections of coal beds in lower Matanuska Valley—Continued.

9. Tunnel A, Chickaloon—Continued.

	Ft.	in.
Coal	2	1
Coal [1]	3	4
Shale [1]		11
Coal [1]	1	10
Shale		5
Coal	2	1
Shale		3
Coal		8
Shale		3
Coal	2	9
Shale		2
Coal	1	0
Bone		7
Shale	12	2
Coal		5
Shale		7
Coal		8
Shale		5
Coal	1	8
Shale		7
Sandstone	7	11
Shale	2	8
Coal		8
Shale		6
Coal	2	3
Shale		5
Coal		5
Shale	3	4
Sandstone	6	1
Shale	18	4
Sandstone	1	0
Shale (at entrance of tunnel)	41	3
Shale (outside of tunnel)	2	6
Coal		6
Bony coal		4
Shale		8
Bone		5
Shale		5

Talus slope.

10. Tunnel B, Chickaloon.

	Ft.	in.
Shale	7	8
Coal	1	3
Bone		4
Coal		6
Sandstone	5	9
Coal	1	9
Bone	1	
Coal	9	8
Streak of bone.		
Coal	4	10
Sandstone	10	8
Shaly coal		7
Sandstone	1	6
Bony coal	2	5
Sandstone	1	1
Coal, with streaks of bone	4	
Sandstone	13	1
Coal	2	4
Sandstone	9	5
Crusted shaly coal	3	
Coal	3	6
Bone	1	
Shale	6	
Coal		10
Bone		3
Coal	4	
Sheared shale	2	
Coal	3	
Bone		7
Sandstone and shale	65	

Strike N. 48° W., dip 76° SW.

11. Tunnel B, Chickaloon.

	Ft.	in.
Shale	7	4
Coal	2	4
Shale with coal and bony beds	5	6
Coal	1	6
Shale		3
Coal	4	3
Shale		2
Coal	1	1
Irregular shale mass		5
Coal		11
Shale		8
Coal		11
Shale		4
Coal	1	6
Shale with many coaly beds		11
Coal	4	2
Shale with coal and bone partings		7
Shale	9	
Coal		7
Shale	2	7
Alternating coal and shale	3	2
Coal	3	10
Shale	12	1
Bony nodules	1	
Coal		5
Shale	8	9
Shale with coaly streaks	1	10
Coal		7
Shale		4

---

[1] Crosscut goes south on these beds.

Sections of coal beds in lower Matanuska Valley—Continued.

11. Tunnel B, Chickaloon—Continued.

	Ft.	in.
Coal	2	4
Shale	1	6
Coal		3
Shale	5	6
Coal		9
Shale		5
Coal with bony bands	2	4
Bone and shale with some coal	1	10
Shale	1	10
Coal and bone [1]		11
Shale and bone [1]		9
Coal [1]	2	10
Shale	11	10
Coaly shale		9
Coal with some shaly streaks	1	5
Shale (entrance of tunnel)	33	

Strike N. 48° W., dip 67° SW.

12. Tunnel No. 2, Chickaloon.

	Ft.	in.
Hard shale.		
Bone		5
Coal [2,3]		8
Bone [2]		5
Coal [2,3]	2	4
Bone [2]	1	11
Coal [2,3]		11
Bony coal [2]		6
Shale and bone	2	8
Coal [2,3]	1	10
Coal, with some bone [2]	2	5
Coal [2,3]		2
Bone [2]		10
Hard shale	17	6
Coal	6	
Shale (at mouth of tunnel)	20	

Dip almost vertical toward mouth of tunnel.

13. Tunnel No. 2, Chickaloon.

	Ft.	in.
Coal	1	1
Shale		4
Coal [4]	2	
Bony coal	1	
Shale		7
Coal	1	2

13. Tunnel No. 2, Chickaloon—Continued.

	Ft.	in.
Shale	1	2
Shale and bony coal	1	3
Coal [5]	3	4
Bony coal and shale	1	7
Shale	18	
Bony coal [6]	1	
Coal [6]	2	9
Bony coal [6]		10
Shale	14	
Timbering	11	

14. Tunnel No. 3, Chickaloon.

	Ft.	in.
Shale	10	
Coal	1	4
Shale		6
Bone		6
Coal [7]	7	
Shale with coal streaks	4	6

Strike N. 81° W., dip 72°, 75°, 83° NE.

15. Tunnel No. 3, Chickaloon.

	Ft.	in.
Coal	1	3
Shale		3
Coal	3	9
Shale	2	
Coal [8]	4	
Shale	16	
Coal [9]	1	9
Shale [9]	2	3
Coal [9]	1	10
Shale with coaly streaks	1	8
Shale	43	
Coal (crosscut goes south)	3	4
Shale		1
Coal		10
Shale	5	
Timbered (entrance of tunnel)	16	

16. Tunnel C, Chickaloon.

	Ft.	in.
Shale [10]	25	
Coal		9
Shale	4±	
Coal	2	6
Coal, more or less shaly	3	2
Shale	9	6
Timbering	12	

---

[1] Crosscut goes S. 77° W. on these beds to tunnel 2. (See note 4.)

[2] Included in sample 1, p. 90.

[3] Included in sample 2, p. 90.

[4] Crosscut goes south on this bed.

[5] Crosscut goes north on this bed to tunnel B. (See note 1.)

[6] Crosscut goes south to raise.

[7] Included in sample 4, p. 90.

[8] Measurement made on floor of tunnel, but coal is cut off entirely at the roof by a fault.

[9] The crosscut going south to raise from tunnel 2 should be on this bed.

[10] The 3 foot 4 inch coal in crosscut going south from tunnel 3 should be the second bed beyond the present face of this tunnel.

Sections of coal beds in lower Matanuska Valley—Continued.

17. Tunnel D, Chickaloon.

	Ft.	in.
Coal	3	8
Shale to end of timber	17	6

Strike N. 80° W., dip 64° NE.

18. Tunnel E, Chickaloon.

	Ft.	in.
Coal	1	5
Bone		6
Coal	1	10
Bone		11
Coal	2	7
Crushed shale and coal	2	10
Coal		10
Sandstone and shale	18	

19. Tunnel No. 5, Chickaloon.

	Ft.	in.
Shale	10	
Coal [1]	1	8
Shale		6
Bony coal	1	8
Shale		10
Coal [1]	6	2
Shale	28	

Strike N. 89° E., dip 51° N.

20. Tunnel F, Chickaloon.

	Ft.	in.
Coal	1	3
Shale		3
Bone and coal		3
Coal	1	5
Shale		8
Coal		4
Bone		2
Coal	2	5
Shale		3
Coal	1	
Shale		8
Coal		10
Shale (to cave-in)	7	

Strike east and west, dip 70° N.

21. East bank of Kings River at bend below coal camp.

[Included in section on p. 47.]

	Ft.	in.
Dark shale with ironstone nodules.		
Coal		1
Shale	1	4
Coal		5½
Parting.		
Coal		10
Shale		6
Coal		3½
Shale		½
Coal		1

21. East bank of Kings River at bend below coal camp—Continued.

	Ft.	in.
Carbonaceous and concretionary shale	12	4
Shale with many thin coal streaks		7½
Coal		8
Gray shale with ironstone nodules, and sandstone	153	
Shale.		
Coal		5
Shale		1
Coal		6¼
Shale		3¼
Shale with small coal streaks and lenses		2
Coal		8
Parting.		
Coal	1	1½
Shale crushed into small pieces and slickensided		6
Coal		2¼
Shale	4	2
Bright coal		8
Coked coal and baked shale	8±	
Diabase sill.		

Strike N. 15° E., dip 31° SE.

22. Tunnel on east bank of Kings River 100 yards above upper bridge.

	Ft.	in.
Dense, impure coke	5	
Bony shale	1	
Coal	1	
Shale		1
Coal		8
Bone		1
Coal	1	2
Bony coal		9
Coal	2	6
Hard shale.		

23. Open cut 10 feet south of preceding section.

	Ft.	in.
Coal (no cover)	3	
Shale		2
Coal	1	2
Soft impure coal		2
Coal	1	8
Shale		3
Coal		3
Shale and coal		7
Coal	2	8
Hard shale floor.		

---

[1] Included in sample 5, p. 90.

Sections of coal beds in lower Matanuska Valley—Continued.

24. Kings River at upper bridge, west side.

	Ft.	in.
Bone and coal		7
Clean coal	1	7
Shale	4	6
Concealed short distance.		
Crushed coal with lenses of bone	5	7
Shale	1	7
Sandy shale	4	
Coal	2	10
Bone		4
Coal	2	10
Coal and bone		8
Coal		11
Bone		½
Coal	2	5

Strike N. 15° W., dip 42° NE.

25. Opening on west bank of Kings Creek at upper bridge.

[On same bed as preceding section.]

	Ft.	in.
Coal[1]	2	5
Sandstone		2
Coal[1]	1	4
Shale		1
Coal	1	5
Sandstone		1
Bony coal[1]	1	
Sandstone		1
Coal[1]	3	4

Strike N. 15° W., dip 42° NE.

26. Gulch on northwest side of mountain 4 miles north of the mouth of Young Creek ("Red Mountain").

	Ft.	in.
Shale.		
Coal (details obscure, total thickness estimated)	7±	
Coal		5
Shale		1½
Coal[2]	1	2
Shale		1
Coal[2]		6
Shale		1½
Coal[2]		7
Shale		¾
Coal[2]		4
Shale		½
Coal[2]		2
Shale		¾
Coal[2]	2	

Strike, on sandstone below, N. 67 E., dip 54° SE.

About 30 feet stratigraphically above section 26 is another coal bed at least 5 and possibly 10 feet thick, and again 30 feet higher and about 80 feet higher are coal beds largely obscured by talus.

27. West bank of Young Creek 3½ miles above mouth.

	Ft.	in.
Shale.		
Coal[3]	1	
Shale	15	
Coal		6
Shale with sandstone bands.		

Strike N. 15° E. (magnetic), dip 20° NW.

28. West bank of Eska Creek, at elevation [illegible] feet.

	Ft.	in
Shale and sandstone.		
Coal[4]	1	3
Shale		1
Coal[4]	1	4
Shale		1
Coal, bony	1	3
Shale		½
Coal, bony	1	1
Shale		1
Coal with some shale and bone	2	6
Shale		6
Coaly shale	2	

Strike N. 57° E., dip 44° NW.

A more complete section in the same bed measures as follows:

29. West bank of Eska Creek, at elevation [illegible] feet.

	Ft.	in
Sandstone	15	
Shale	2	6
Coal		7
Parting.		
Coal		5
Parting.		
Coal		5
Parting.		
Coal	1	6
Coal with shaly streaks		7
Coal		10½
Shale		1–2½
Coal (a hard stony nodule was seen in this bed)	1	1
Coaly shale	1	5
Coal		1
Shale		1
Coal		3½
Coaly shale		3

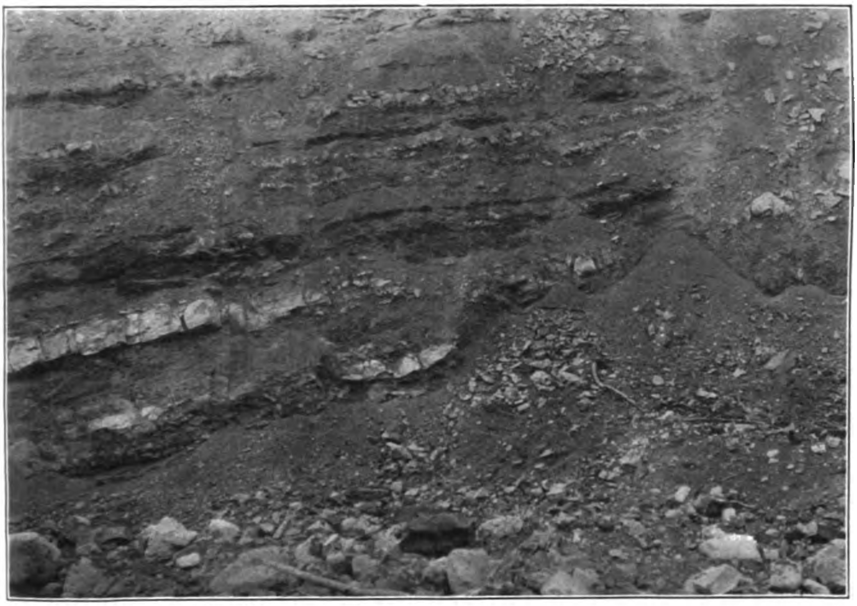
---

[1] Included in samples 12 and 13, p. 90.

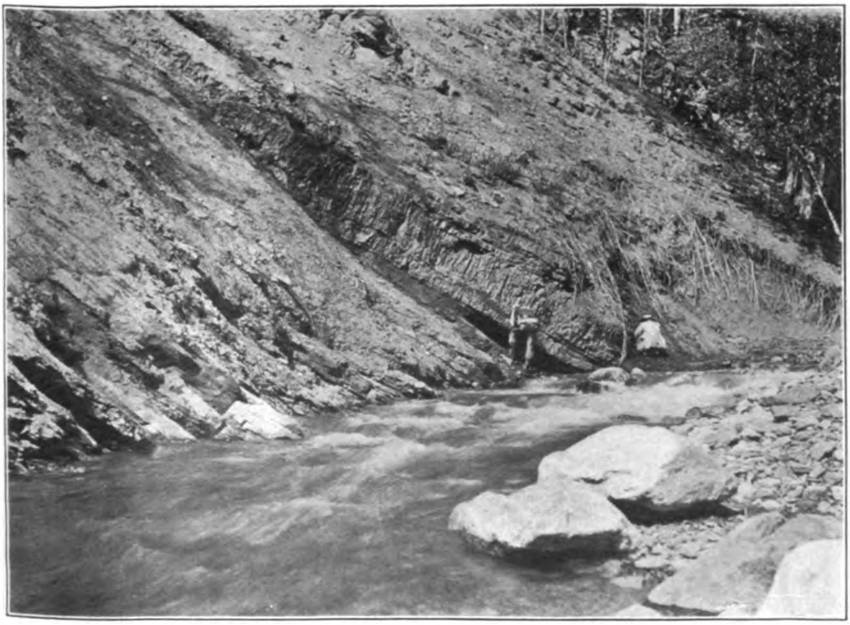
[2] Included in sample 1–1910, p. 90.

[3] Included in sample 16, p. 90.

[4] Included in sample 17, p. 90.



A. COAL BEDS IN WEST BANK OF ESKA CREEK 2.7 MILES NORTH OF MATANUSKA RIVER.



B. COAL BED IN WEST BANK OF ESKA CREEK 2.4 MILES NORTH OF MATANUSKA RIVER.

Sections of coal beds in lower Matanuska Valley—Continued.

29. West bank of Eska Creek, at elevation 925 feet—Continued.

	Ft.	in.
Shale	1	
Coal (a hard stony nodule was seen in this bed)		7
Parting.		
Coal		8
Shale		½–1
Coal with several thin shaly beds		10
Shale		8
Coaly shale		8
Coal with many thin shale bands	1	7
Coal (with silicified logs, especially at the top)	1	2–4
Shale	24±	

Major cleat S. 42° E., dip 83° SW., not well developed.

Strike N. 57° E., dip 42° NW.

30. West bank of Eska Creek about 300 feet upstream from preceding section.

Shale roof.	Ft.	in.
Coal[1]	3	3
Shale		3
Coal		11
Shale		5
Coal		6
Shale		6
Coal		4
Shale		1
Coal		9
Soft black shale.		

Dip northwest.

31. West bank of Eska Creek 3,600 feet below forks.

[Shown in Pl. XVII, *B*.]

Shale.	Ft.	in.
Shale with thin coal beds	3	9
Coal	1	
Coaly shale		2
Coal		9
Rusty shale		1
Coal		6½
Parting.		
Coal		1½
Parting.		
Coal		4
Shale parting.		
Coal	1	9
Rusty shale		1½–2
Coal		4 –6
Shale		2½
Coal		5
Sandstone		1 –2
Bony shale		2½
Coal		3½
Shale and arkose.		

Strike west, dip 36° N.

About 100 feet above is the following section:

32. West bank of Eska Creek 3,600 feet below forks.

Shale.

Concealed.	Ft.	in.
Coal		5
Shale		1½
Coal (clay-ironstone nodules in a 2½ to 5 inch layer near top)	2	2
Shale		1½
Coal	1	1
Shale		2½–3½
Shale with veins of coal	1	5
Coal		3
Shale with veins of coal		7
Coal		6½
Shale parting		½
Coal		8½
Shale		½–1
Coal		2½
Coaly shale		11
Shale.		

Major cleat S. 30° E., dip 90°. Minor cleat N. 53° E., dip 50° SE.

33. East bank of Eska Creek, at elevation 960 feet.

Shale.	Ft.	in.
Coaly shale		1
Sandstone		1½
Coaly shale		1½
Coal		1½
Shale		2
Coal[2]	2	8
Parting.		
Coal with shaly bedding	1	
Shale and arkose	22	
Arkose	7	

---

[1] Included in sample 18, p. 90.

[2] Major cleat S. 43° E., dip 88° NE.; minor cleat not well developed.

Sections of coal beds in lower Matanuska Valley—Continued.

33. East bank of Eska Creek, at elevation 950 feet—Continued.

	Ft.	in.
Concretionary shale	4	10
Coal and shale in minute beds		6
Shale		1
Coal[1] (contains silicified log near top)	3	4
Parting.		
Coal		3
Parting.		
Coal, with shaly bedding, consisting of a mat of leaves concealed	2	

Strike N. 50° E., dip 18° SE.

34. Base of cliff on west bank of Eska Creek, at elevation 1,000 feet.

	Ft.	in.
Shale, concretionery.		
Black shale with coaly streaks	1	
Coal		1
Shale		1
Coal	1	4
Shale		1
Coal	1	
Coal with thin shaly bands.	1	5
Shale		8
Coal		7
Shale	1	

Strike N. 62° E., dip 35° SE. Major cleat S. 48° E., dip 84° NE.

35. West bank of Eska Creek, at elevation 1,000+ feet.

	Ft.	in.
Sandstone (cliff)	75±	
Soft sandstone	9	
Shale with little coal	2	
Concealed, mostly shale	80	
Coal	4	2
Shale	1	5
Coal		7
Shale		11
Coal		1
Shale, some coal, and ironstone concretions	2	
Coal with several shale beds	3	9
Shale with ironstone concretions	9	6
Coal (with shaly bedding in part and many thin shale partings)	13	
Shale	3	6

35. West bank of Eska Creek, at elevation 1,000+ feet—Continued.

	Ft.	in.
Ironstone		6
Shale	3	
Ironstone	2	
Shale	5	
Coal		9
Shale with seams of coal	1	1
Coal	2	
Shale		2½
Coal		4
Shale		2
Coal	2	8
Shale		7
Coal	1	9
Shale with veins of coal	2	1
Coal	1	1
Shale		2
Coal containing clay-ironstone nodules	5	
Shale		1½
Coal		2
Shale		1½
Coal		3
Shale		2
Coal		1
Shale	1	10
Shale with bands of coal		6
Shale		6
Coal		2
Shale with ironstone bands	14	6
Ironstone	1	3
Shale	4	7
Coal	1	3
Shale	5	9
Coal		8
Shale	6	
Ironstone	1	3
Gray shale	15	
Ironstone	2	
Shale	28	

36. West bank of Eska Creek about 1,250 feet below forks.

	Ft.	in.
Sandstone.		
Shale	7	3
Coal and shale		6
Coal	3	6
Shale with thin coaly streaks	1	
Coal		8
Shale with occasional streaks of coal	2	8
Coal with many shale bands	1	

---

[1] Major cleat N. 42° E., dip 76° SW.

Sections of coal beds in lower Matanuska Valley—Continued.

36. West bank of Eska Creek about 1,250 feet below forks—Continued.

	Ft.	in.
Shale	2	9
Coal with many shale bands	2	5
Shale with occasional coal lenses	4	
Ironstone nodules		2–5
Shale	2	7
Bright coal (a nodule seen near top)	3	7
Coal with many thin shaly bands	1	5
Shale		8
Coal, somewhat shaly		4½
Coal and shale	1	3
Coal		3
Shale		1½
Coal		1½
Parting.		
Coal		11
Shale		2
Coal		6
Shale and coal		2
Coal		4
Shale and coal		1½
Coal, bright	1	4
Coal with many thin shale bands	1	2
Gray shale	2	4
Shale with standstone lenses and ironstone nodules	3	
(Continued about 60 feet downstream on account of fault (?). Where recommenced there is only 34 feet to base of sandstone heading this section.)		
Shale with a few coaly streaks	2	
Ironstone nodules		3
Shale with coaly lenses	1	2
Bright coal		4
Shale		4
Bright coal	1	
Parting.		
Coal		9
Parting.		
Coal		5
Shale	1	2
Bright coal	1	2
Shale		½
Coal with shaly bands		8
Shale		10
Coal lens	0–2±	
Shale	1	4
Coal		2–5
Shale	2	8
Ironstone nodules		4–6
Shale	5	9
Ironstone nodules		0–10
Shale	3	
Coal		2–6
Shale	1	5
Coal with shaly bands	1	
Shale		3
Coal with shaly bands		7
Shale		4
Coal with shaly bands		6
Shale	13	
Ironstone nodules		6–18
Shale	2	
Coal with shaly bands	1	2
Bright coal		9
Parting with lenses of sandstone and shale		0–½
Bright coal		10
Shale with some coal		1–2
Sandstone	3	9

Strike N. 22° E., dip 45° NW.

37. West bank of Eska Creek about 1,100 feet below forks.

[Part of this section shown in Pl. XVII, *A*, p. 82.]

	Ft.	in.
Sandstone	75±	
Shale	1	
Coal		1½
Shale		2
Coal	1	4½
Parting.		
Coal		8½
Shale		½
Dirty coal		9½
Coaly shale		10
Coal		8
Coaly shale	4	9
Shale	4	2
Coal	1	1
Coaly shale		10

Sections of coal beds in lower Matanuska Valley—Continued.

37. West bank of Eska Creek about 1,100 feet below forks—Continued.

	Ft.	in.
Shale	8	
Coal	2	2
Shale		1
Coal	1	2
Parting.		
Coal	1	
Coaly shale	2	10
Coal		4
Shale		1
Coal		9
Shale		½
Coal		2½
Shale		1
Coal		9
Shale		½
Coal		2
Shale		1
Coal	1	7
Shale with thin bands of coal		3
Shale	3	9
Shale with thin bands of coal	4	2
Coal	1	5
Shale		6
Coal		5
Shale		2
Coal	2	
Shale with ironstone nodules		9
Coal		3
Shale		1½
Coal	1	4
Shale with coaly bands		5
Coal	1	3
Shale		1½
Coal		5
Shale with few thin bands of coal	2	3
Coal		4
Shale with many bands of coal		8
Shale, with ironstone	13	4
Shale with a few bands of coal		7
Coal (not well exposed where measured)	2	
Shale	3	
Coal		2½
Shale		3½
Coal		10
Shale		2½
Coal		6
Shale with thin bands of coal		2½
Shale with some ironstone	27	6
Sandstone, upper foot shaly	4	
Shale with some ironstone nodules and petrified sticks	19	6
Ironstone		3
Shale with bands of coal	1	9
Coal		7½
Parting.		
Coal	1	1
Shale	3	
Ironstone		4
Shale	1	3
Ironstone		3
Shale	1	
Shale with bands of coal		10
Shale		7
Coal		6
Shale	1	10
Coal		5
Shale		10
Coal		4–12
Shale with bands of coal	1	4
Shale with sandstone and ironstone nodules (cliff)	37	
Coal (petrified log seen in this bed)		10
Coaly shale		2
Ironstone		4–8
Shale	8	
Ironstone		8
Shale	3	5
Ironstone nodules		7
Shale with ironstone nodules	3	4
Shale with little stringers of coal		5
Shale	1	10
Shale with coaly streaks		10
Ironstone nodules		5
Shale with ironstone nodules	3	

Sections of coal beds in lower Matanuska Valley—Continued.

37. West bank of Eska Creek about 1,100 feet below forks—Continued.

	Ft.	In.
Clay ironstone	2	10
Gray fissile shale	4	
Sandy shale, somewhat massive	3	

38. Eska Creek 1,550 feet above third forks, at elevation 1,650 feet.

	Ft.	In.
Shale.		
Coaly shale		6
Coal		5
Coaly shale	2	
Coal with many thin shale bands	6	
Shale.		

Strike N. 66° E., dip 65° SE.

39. East bank of Moose Creek 13,000 feet above U. S. land monument No. 5.

	Ft.	In.
Carbonaceous shale with ironstone nodules.		
Carbonaceous shale with seams of bony coal	1	
Coal		7
Bone and shale		1
Coal		10
Bone		2
Coal		9
Shale with coaly streaks	7	
Coal	1	
Shale		1½
Coal		3
Shale		½
Coal	1	5
Bone		1
Coal		10
Nodular shale.		

Strike N. 65° E., dip 83° SE.

40. East bank of Moose Creek about 100 yards below upper cabin.

	Ft.	In.
Coal with hard ferruginous inclusions	3	
Shale	2	
Coal (bright)[1]	4	6
Shale		2
Coal (bright and hard)[1]	7	
Soft shaly coal	1	
Soft shale with abundant iron-ore concretions.		

Strike N. 77° E., dip 43° NW.

41. East bank of Moose Creek 700 feet above U. S. land monument No. 5.

	Ft.	In.
Shale	58	
Arkose	8	
Shale	10	
Bone		1
Parting.		
Coal[2]		8½
Parting (slickensided).		
Coal		7
Coal, somewhat bony		4
Coal with shaly bands		14
Black shale with few coaly streaks		5
Coal with shale streaks		6
Black shale	2	
Ironstone concretions	2	
Black and gray shale	10	
Coal, dirty	3	
Shale	3	
Coal with lenses of ferruginous nodules 2 inches thick	1	6
Shale with some coal	1	6
Shale with ironstone nodules	3	
Impure coal		10
Shale with ironstone nodules	2	
Coal with much shale	1	
Shale and ironstone nodules	4	
Impure coal	1	
Shale with nodules and a few thin bands of coal	10	
Coal with lenses of ferruginous nodules, 2 inches thick	3	

Strike N. 78° E., dip 71° NW.

42. One-eighth of a mile below upper cabin, Moose Creek.

	Ft.	In.
Shale and sandstone roof.		
Dirty coal		7
Shale	3	
Sandstone nodules	1	
Bone and coal	1	3
Bone		1
Coal		3
Bone and shale	3	
Coal	1	3
Bone		1
Coal		5
Shale	1	

---

[1] Included in sample 20, p. 91.

[2] Major cleat N. 65° E., dip 48° SE; minor cleat N. 25° W., dip 74° NE.

Sections of coal beds in lower Matanuska Valley—Continued.

42. One-eighth of a mile below upper cabin, Moose Creek—Continued.

	Ft.	in.
Shale and sandstone	3	6
Coal		8
Shale	1	
Shale and sandstone	3	4
Coal		8
Shale and bone	1	6
Shale	25±	
Clear coal	3	6
Slide.		
Coal		8

43. Near upper end of Moose Creek gorge at elevation 700 feet.

	Ft.	in.
Sandstone.		
Coal		2
Sandstone		1
Bright coal [1]	2	4
Shale		6
Bright coal [1]	2	
Dull coal [1]	1	2

43. Near upper end of Moose Creek gorge at elevation 700 feet—Continued.

	Ft.	in.
Shale		4
Dull coal	1	6
Shale.		

Strike N. 7° E., dip 24° SE.

44. East bank of Moose Creek 1,550 feet below United States land monument No. 5.

	Ft.	in.
Shale.		
Coal		2
Shale		2
Coal	1	4
Ferruginous nodules		2
Coal		5
Coal and shale		9
Coal		6
Bone		½
Coal	1	
Coal with several thin beds of shale	2	3
Gray shale.		
Sandstone.		

Strike N. 29° E., dip 42° SE.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coal of the Matanuska Valley is of three kinds—anthracite, high-grade bituminous, and low-grade bituminous. Of these only the last two have been found within the area mapped in detail in the investigations here described. The anthracite occurs farther east and has been described in earlier reports.[2]

The high-grade bituminous coal occurs on the south side of the Matanuska, east of and in the vicinity of Coal Creek, and on the north side of the river in the valleys of Chickaloon and Kings rivers. The low-grade bituminous coal is known in the valleys of Young, Eska, and Moose creeks.

The high-grade bituminous coal is fragile and soft, like most coal of this kind, and the beds show the effects of having been severely crushed and at many places are without any well-defined bedding planes or planes of fracture. The friability of the coal is such that it will probably not stand shipment without being badly crushed. This is not so great a detriment as might at first seem, because many of the beds contain so many impurities that the coal from them ought to be crushed and washed. It is, moreover, highly probable that much of this coal will be used in the manufacture of coke, a purpose for which lump coal is not desired. Coal which possesses coking properties, as much or all of this coal does, can be burned as slack about as well as in lumps, for the slack coal when thrown into the furnace will fuse and cake, thus preventing loss of coal through the grates.

---

[1] Included in sample 19, p. 91.

[2] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska: Bull. U. S. Geol. Survey No. 289, 1906, pp. 18–19, 26–30. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 52–56, 59–63.

The low-grade bituminous coal on Moose, Eska, and Young creeks is on the border line between bituminous coal and black lignite. It is harder than the higher-grade coal farther east. Many of these beds have not been crushed and a larger proportion of lump coal can probably be obtained from them in mining than from the coal beds described above. This coal possesses no coking properties and will probably be used under stationary or locomotive boilers. It is not so good for this purpose as the coal from the east end of the field, but, because the latter is well suited for the manufacture of coke and for use as smithing and naval coal, it will command a higher price and thus probably leave a lower-price market for the poorer coal farther west. The low-grade coal can probably be mined and shipped more cheaply than the high-grade coal. The two kinds of coal will, to a certain extent, be noncompetitive, each having its own special markets.

CHEMICAL ANALYSES AND TESTS.

The following table includes characteristic analyses of coals from various parts of the area. Sample 1–1910 was taken during the investigations here described. The other analyses have been published in Bulletins 289 and 327 and represent samples collected in 1905. All the samples except Nos. 2215 and 2227 were obtained from surface prospects or from outcrops and were consequently somewhat weathered. Samples 2215 and 2227 came from a tunnel at a distance of 43 to 58 feet from the mouth of the tunnel and probably under about 25 or 30 feet of cover.

Proximate analyses of Matanuska coals.

No. of sample.	Locality.	Laboratory number.	Thickness of coal seam, in feet.	Moisture in air-dried sample.[a]	Total moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories[b] per pound of coal.	Recalculated.		
											Fuel elements.		Fuel ratio.
											Volatile matter.	Fixed carbon.	
1	Chickaloon River, tunnel No. 2	2215	12.3	0.98	2.58	19.14	67.46	10.82	0.57	....	22.10	77.90	3.52
2	Chickaloon River, tunnel No. 2 (selected)	2227	5.2	(c)	.90	19.60	74.60	4.90	.60	8,260	20.81	79.19	3.81
3	....do	....	....	(c)	1.06	12.76	78.96	6.28	.90	....	13.91	86.09	6.19
4	Chickaloon River, tunnel No. 3	2216	7.0	1.46	2.46	17.01	53.23	27.30	.84	....	24.22	75.78	3.13
5	Chickaloon River, tunnel No. 5	2220	7.9	1.00	2.90	17.47	56.15	23.48	.46	....	23.73	76.27	3.21
	Average of analyses 1-5	....	....	....	1.98	17.20	66.08	14.56	.67	....	20.95	79.05	3.77
6	Matanuska River, south side, 3 miles above Chickaloon Creek	2214	7.0	2.76	4.36	18.92	61.19	15.53	.37	....	23.62	76.38	3.23
7	....do	....	7.0	(c)	4.15	20.63	59.62	15.60	.34	....	25.71	74.29	2.89
8	Coal Creek, ¼ mile above mouth	2217	5.0	1.44	2.24	23.08	70.21	4.47	.50	....	24.74	75.26	3.04
9	....do	....	5.0	(c)	1.88	22.51	71.65	3.96	.44	....	23.91	76.09	3.18
10	Coal Creek, ¾ mile above mouth	2219	8.6	2.64	6.74	14.96	65.83	12.47	.44	6,649	18.52	81.48	4.40
11	....do	....	8.6	(c)	5.83	18.24	63.03	12.90	.47	....	22.44	77.56	3.46
	Average of analyses 6-11	....	....	....	4.20	19.72	65.26	10.82	.42	....	23.14	76.86	3.32
12	Kings River, west bank, upper bridge	2218	9.9	1.13	2.93	21.85	63.09	12.13	.59	7,419	25.72	74.28	2.89
13	....do	....	9.9	(c)	1.22	24.15	62.65	11.98	.52	....	27.82	72.18	2.59
14	Kings River	....	....	(c)	1.15	23.09	69.34	6.42	.89	....	24.98	75.02	3.00
15	....do	....	....	(c)	.50	22.00	70.50	7.00	....	....	23.78	76.22	3.20
	Average of analyses 12-15	....	....	....	1.45	22.77	66.40	9.38	.67	....	25.57	74.43	2.91
16	Young Creek, 3 miles above trail	2223	1.0	(c)	2.50	28.32	58.82	10.36	.58	....	32.50	67.50	2.08
	Average of analyses 1-16	....	....	....	2.71	20.23	65.39	11.60	.57	....	23.65	76.35	3.23
1-1910	Red Mountain (Young Creek)	11382F	12.2	4.76	10.57	33.80	50.57	5.06	.23	6,236	40.07	59.93	1.50
17	Eska Creek, 3 miles above trail	2226	2.6	(c)	5.56	36.52	51.32	6.60	.42	....	41.58	58.42	1.41
18	....do	2224	3.3	(c)	6.60	34.30	48.23	10.87	.41	6,299	41.56	58.44	1.41
	Average of analyses 17-18	....	....	....	6.08	35.41	49.78	8.23	.42	....	41.57	58.43	1.41

19	Moose Creek, 4 miles above trail	2225	6.0	(c)	4.03	34.8[illegible]	49.31	11.82	.38	....	41.40	58.60	1.42
20	Moose Creek, 4½ miles above trail	2221	11.7	5.45	10.05	36.05	48.90	5.00	.25	....	42.44	57.56	1.36
	Average of analyses 19–20	....	....	....	7.04	35.45	49.10	8.41	.32	....	41.92	58.08	1.39
	Average of analyses 17–20	....	....	....	6.56	35.43	49.44	8.32	.37	....	41.74	58.26	1.40

[a] Determined by drying in the open air until weight becomes constant.

[b] A calorie is the amount of heat necessary to raise the temperature of 1 pound of water 1° C. It is equal to 1.8 British thermal units.

[c] Not determined.

1-2, 4-6, 8, 10, 12, 16-20. Sampled by G. C. Martin. Analyses by F. M. Stanton, U. S. Geological Survey coal-testing plant, St. Louis, Mo.
7, 9, 11, and 13. Sampled by William Griffith and G. C. Martin. Analyses by A. S. McCreath, Harrisburg, Pa.
14. Sampled by George Jamme. Analysis by C. C. Bogardus, Seattle, Wash. Published in Bull. U. S. Geol. Survey No. 259, 1905, p. 170.
15. Sampled by Frank Watson. Analysis by William H. Stowell & Co., Seattle, Wash.
1-1910. Sampled by G. C. Martin. Analysis by A. C. Fieldner, U. S. Bureau of Mines.

Analyses [a] and tests of Matanuska coals.

Sample No.	Thickness of coal in feet.	Proximate analysis.					Ultimate analysis.					Calorific value.	
		Loss on air-drying.	Total moisture.	Volatile combustible.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	12.3	1.60	2.55	16.66	69.72	11.07	0.57	4.19	76.58	1.37	6.22	7,545	13,581
2	5.2	....	.99	19.03	75.19	4.79	.60	4.71	83.90	1.48	4.52	8,205	14,769
8	5.0	.80	1.97	18.58	75.19	4.26	.50	4.80	82.77	1.79	5.88	8,146	14,663
12	9.9	1.80	2.68	20.69	64.72	11.91	.59	4.68	74.38	.87	7.57	7,422	13,360
1-1910	12.2	6.10	10.57	33.80	50.57	5.06	.23	5.41	65.16	1.13	23.01	6,236	11,225
17	2.6	....	4.74	34.79	54.06	6.41	.42	5.54	71.06	1.60	14.97	6,985	12,573
18	3.3	....	5.00	33.90	50.65	10.45	.41	4.77	63.59	1.38	19.40	6,338	11,408
19	6.0	....	4.75	32.64	50.63	11.98	.38	4.76	64.09	1.09	17.70	6,428	11,570
20	11.7	4.60	9.49	33.63	51.71	5.17	.25	5.52	65.85	1.20	22.01	6,445	11,601

[a] These analyses were made by F. M. Stanton on the same samples as those with corresponding numbers in the preceding table. The differences in proximate analyses are due to the fact that the samples dried somewhat in the months which elapsed between analyses, and that somewhat different methods of analysis were used. (See Bull. U. S. Geol. Survey No. 290, 1906, pp. 29–30.)

COKING QUALITIES.

A rough test of the coking qualities of the coal from tunnel No. 2 on Chickaloon Creek (see p. 80) was made during the summer of 1905 by coking a large pile of coal under a covering of stones and dirt. The resulting coke was hard and firm and had a good ring and a good texture. The test indicated that by proper treatment a coke of satisfactory grade can be produced.

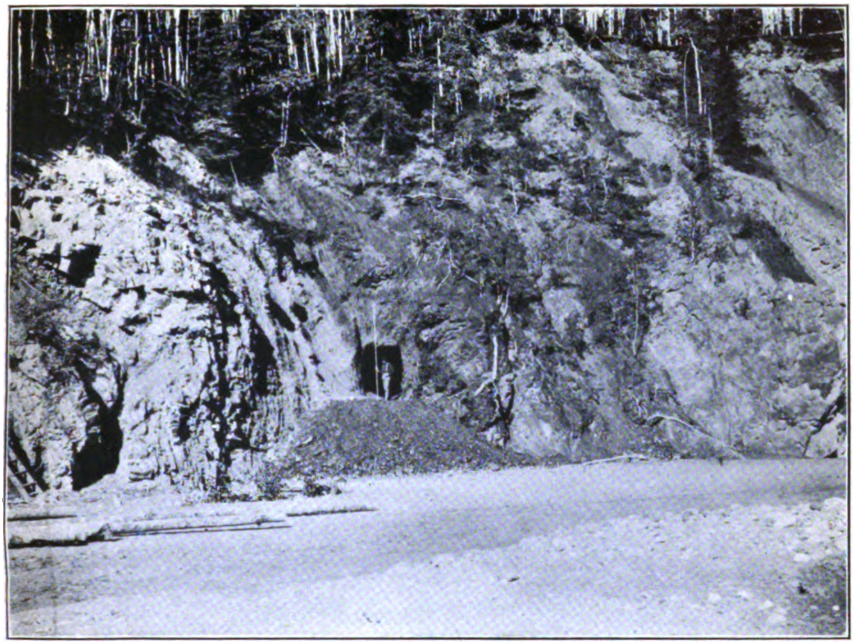
No further tests have been made by members of the Geological Survey. The analyses indicate, however, that the high-grade bituminous coal on Chickaloon and Kings rivers and on Coal Creek is probably, at least in part, coking coal, and that the coal in the west end of the district, on Moose, Eska, and Young creeks, is low-grade bituminous and is probably all noncoking coal.

MINING CONDITIONS.

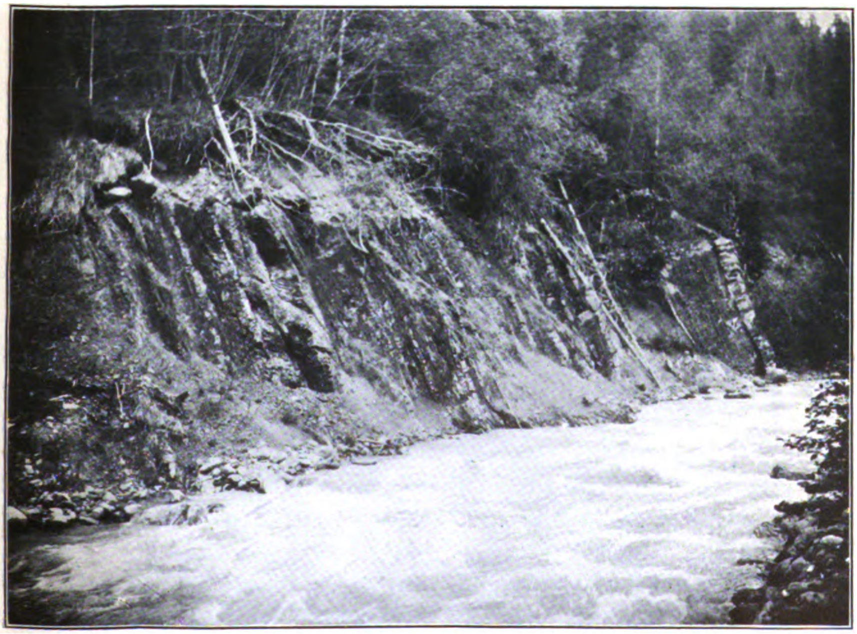
MINE SITES.

Mine sites should be selected only after a careful study of local conditions accompanied by drilling. The selection of a site should be governed by the accessibility to the railroad and by the structure of the rocks. The latter should be determined in detail for each property by careful drilling or otherwise, in order that the mine may be opened at such a point that the underground haulage of the coal and the disposal of the mine waters may be accomplished at a minimum expense.

Although many of the coal beds outcrop at the surface, the outcrops dip for the most part at steep angles. (See Pl. XIX.) Few if any localities have been found at which it would be possible to open an extensive mine on the outcrop of the coal bed. The amount of coal above the general drainage level is not great and it will be necessary from the very beginning of mining to sink shafts or slopes to consider-



A. COAL BED IN WEST BANK OF CHICKALOON RIVER AT BEND ABOVE COAL CAMP.



B. COAL BED IN EAST BANK OF COAL CREEK SEVEN-EIGHTHS OF A MILE ABOVE ITS MOUTH.

able depths. When any large mines are opened it will probably be found desirable to sink shafts to the coal beds at considerable distances from their outcrops.

LOCAL SUPPLIES.

The local region will furnish none of the supplies needed in coal mining except timber. Everything else will have to be shipped from outside of Alaska. The development of this field on a large scale will consequently probably involve the building up of other industries, such as establishments for the manufacture of mine cars and other machinery and mine supplies.

UNDERGROUND WATER AND GAS.

In any large mines which are opened in this region it will be necessary from almost the beginning of mining to pump or hoist mine water. It is not believed that it will be possible to open any large mines having natural drainage. The amount of underground water which will be encountered will probably not be great, unless the mines are opened on the outcrop. Precipitation in this region is so slight that large amounts of water can get into the mines only from the streams. If ordinary precautions are taken to prevent streams from breaking into the mine openings the mines ought to be fairly dry.

The heavy cover of gravel which exists at the lower altitudes throughout most of the Matanuska Valley will cause certain dangers in mining. Unless the depth of the gravel at different points and the shape of the underlying rock floor are determined by drilling there will be danger of the mine workings breaking through the surface of the rock into the gravels. The gravels probably carry large amounts of water in some places and serious accidents might thus result.

Gas will probably be a serious problem in local mining from the very start. The experience of the few small tunnels which have been driven indicates that these coal beds will yield large amounts of dangerous gases. Some provision ought to be made in advance of mining for the enforcement of suitable regulations insuring the protection of the miners and the mines against gas explosions.

EFFECT OF INTRUSIVE ROCKS.

Intrusive rocks are known to be present in abundance and in large masses throughout the greater part of the area of coal-bearing rocks, except in the valleys of Moose and Eska creeks, where they are small and are much less numerous than farther east. The areal distribution of the larger of these intrusive masses is indicated on the map (Pl. V, in pocket). Small dikes and sills, not represented on the map, are also present throughout practically all the coal areas. Where the intrusive rocks cut the coal beds the coal is rendered worthless for a distance of a few inches from the contact. The small dikes and sills, on account of the short distances to which their effect extends, do not affect the coal seriously, except that the sills show a habit of seeking coal beds for their planes of intrusion. It is clear that if a sill is intruded into a coal bed for a long distance a large amount of worthless coal will result, but if it is intruded between rock strata, even if only a few feet away from a coal bed, or if it cuts across the coal bed in the form of a dike, its effect on the coal will be slight.

The larger intrusive masses are of much more serious importance than the small dikes and sills, first, because their size is of itself sufficient to reduce the coal areas considerably, and second, because each of them is likely to have sent off many apophyses in the form of sills in or along the surfaces of coal beds. The dimensions of these masses are, moreover, probably greater under ground than at the surface. There may also be many intrusive masses which do not outcrop but which are near enough to the surface to be encountered in mining.

In conclusion, it must be stated that the presence of intrusive rocks in the coal field introduces factors that make an undetermined percentage of the coal areas of very doubtful value. The size and distribution of these intrusive masses beneath the surface, as well as at the surface in the areas of scanty outcrops, can not be determined without underground exploration. The effect of the smaller intrusive masses on the coal depends on the extent to which these masses have been intruded into or along the surfaces of coal beds. Where the intrusive mass is in contact with the coal the coal is worthless, but where it is a few feet away the quality of the coal is probably unimpaired, or may even be improved.

EFFECT OF FOLDING AND FAULTING.

The steep dips and complex structure of much of the coal areas introduce serious problems in coal mining and call for careful investigation of the structural conditions of each individual tract before the development of mines is attempted. It is believed that areas will be found in which the difficulties of mining, due to structure, will not be serious.

Both Castle Mountain and Wishbone Hill are of fairly simple structure, so that, if the coal beds persist beneath the conglomerate and if the coal-bearing rocks were not folded before the conglomerate was laid down, mining should not be difficult, at least so far as structural conditions are concerned.

It may perhaps be assumed to be probable that the structures of the entire valley are of the same general type as those known in the areas of the conglomerate. If this is the case, there are probably large areas in which the structure will permit the mining of the coal. This condition is not, however, positively known, and the character of the structure must be regarded as a problem to be solved by underground exploration before the feasibility of mining at a profit the coal of any particular tract can be demonstrated.

METALS.

Within the area covered by the detailed investigations on which this report is based there are no known metalliferous deposits. Indications of metalliferous mineralization were seen only at localities along the great fault which marks the contact of older rocks with the Upper Cretaceous and Tertiary sediments of the Matanuska basin. At one place a thin stain of copper carbonates was seen on crushed and altered granite in the fault zone. At another place crushed, epidotized, and quartz-veined rock carries iron pyrites. Copper stains were observed at the contact of the limestone and the underlying volcanic rocks on the ridge north of Castle Mountain. Colors of gold are reported to have been found in the gravels of Granite Creek.

In the environs of the region considered there are prospects to the east on Caribou Creek and to the north on Kings River and Moose Creek, and there are mines and prospects to the west in the Willow Creek region.

A little placer gold is reported to have been produced on Caribou Creek. No details are known about the occurrence of the gold.

Claims located on copper prospects in the basin of Kings River about 12 miles above the mouth have not been visited by members of the Survey, and no information about them is at hand.

It is reported that sulphide mineralization has been found in the granite area of the upper part of Moose Creek.

Willow Creek produced some placer gold in 1898, and gold placer mines on Grubstake Gulch began producing in 1900. The Grubstake Gulch deposits are in the area of albite-chlorite schists discussed on page 15. (See also Pl. III in pocket.) These deposits have been described in earlier publications of the Survey.[1] In the Willow Creek region gold-quartz prospects are being developed. These are in quartz veins which traverse quartz diorite. Several veins of promising character have been located in the divides between the headwaters of Willow Creek and tributaries of Little Susitna River. They have been described by Katz[2] in a recent publication of the Survey.

The crystalline rocks in which the above-noted prospects and mines occur occupy most of the mountain province north of Matanuska River and west of Chickaloon River.

Nothing has been learned concerning the copper prospects noted by Paige and Knopf[3] in the Knik River and Kashwitna River regions.

---

[1] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 65–67. Katz, F. J., A reconnaissance of the Willow Creek gold region: Bull. U. S. Geol. Survey No. 480, 1911, pp. 139–152.

[2] Katz, F J. op. cit.

[3] Paige, Sidney and Knopf, Adolph op. cit., pp. 67–68.

INDEX.

A. Page.

Agglomerate, distribution, character, and age of........ 29-32
Alaska, central portion of, map showing........ 10
Alluvium, character and distribution of........ 71-72
Arkose, character and distribution of........ 39-42
  in Sheep Valley, plates showing........ 28
  near Moose Creek, plate showing........ 40

B.

Basaltic lavas, character and distribution of.. 54-55
Boulder Creek, gabbro in shale near, figure showing........ 67
Brooks, A. H., preface by........ 7-8

C.

Castle Mountain, Eska conglomerate of, plates showing........ 52,56
  relations of gabbro and Tertiary sediments at, figure showing........ 66
  section of rocks in and figure showing.... 55
Chapin, Theodore, work of........ 10
Chickaloon, coal beds at........ 78-81
  meteorological observations at........ 12
  relation of diabase to Chickaloon formation at, figure showing........ 65
  relation of gabbro to Chickaloon formation near, figure showing........ 66
  tunnels at, figure showing........ 78
Chickaloon coal camp, sections of Chickaloon formation at........ 43-46
Chickaloon formation, character and distribution of........ 42-52
  diabase dikes in, plate showing........ 64
  folded beds of, figure showing........ 60
  fossils of........ 49-52
  sections of........ 43-46, 47-48, 49
  sills and dikes in, figures showing........ 65, 66
Chickaloon River, coal bed near, plate showing........ 92
  coal beds on or near, sections of........ 77, 78
  porphyry sills and dikes near, plate showing........ 56
  relation of diabase sills to Chickaloon formation near, figures showing.... 66, 67
  section of Chickaloon formation near..... 43-44
Coal, areal distribution of........ 75-76
  areal distribution of, map showing.. In pocket
  beds of, descriptions of........ 76-88
    plates showing........ 82, 92
  character of........ 88-89
  chemical analyses of........ 89-90
  coking qualities of........ 92
  mining conditions of........ 92-94
  stratigraphic occurrence of........ 77

Page.

Coal Creek, coal bed near, plate showing..... 92
  coal beds on, sections of........ 77-78
Climate, features of........ 11-12
Commerce, development of........ 14
Conglomerate, Tertiary, character and distribution of........ 39-42
Copper, occurrence of........ 95
Cretaceous rocks, character and distribution of........ 22-23

D.

Diabase, character and distribution of........ 63-67
  dikes and sills of, figures showing........ 65, 66
  dikes of, plate showing........ 64
Diorite porphyries, character and distribution of........ 56-61
  relation of, to sediments, figures showing. 59, 60

E.

Eska conglomerate, character and distribution of........ 52-54
  plates showing........ 52, 56
Eska Creek, coal beds of, plate showing..... 82
  coal beds on, sections of........ 82-87
  Eska conglomerate near, plate showing.. 52
  section of Chickaloon formation on....... 48

F.

Faulting, effect of........ 94
Faults, plate showing........ 72
Fauna, Lower Jurassic, report on... 20, 22, 30, 31-32
  Tertiary, report on........ 52
  Upper Cretaceous, report on........ 36-39
Flora, Tertiary, report on........ 42, 49-52
Folding, effect of........ 94

G.

Gabbro, character and distribution of........ 63-67
  in shale near Boulder Creek, figure showing........ 67
  sills and dikes of, figures showing........ 66, 67
Gas, in mines, effect of........ 93
Geography, account of........ 10-11
Geology, detailed discussion of........ 26-72
  general features of........ 14-26
  structural features of........ 72-75
Gneissic rocks, distribution, age, and character of........ 26-29
Gold, occurrence of........ 95
Granite, relations of, to arkose, in Sheep Valley, plates showing........ 28
Granite Creek, Upper Cretaceous rocks of, section of........ 34-35
Granitic rocks, character and distribution of........ 19, 26-29

Page.
Gravel beds, plate showing.................. 70
Graywackes, of Knik River, character of..... 16-17

H.

Hollick, Arthur, on Tertiary fossils....... 42,49-51

I.

Intrusive rocks, effect of.................. 93-94
Investigations, account of.................. 9-10

J.

Jurassic rocks, character and distribution of. 17-22

K.

Kats, F. J., work of.......................... 10
Kings Creek, coal bed on...................... 82
Kings River, coal beds on or near............ 81-82
  section of Chickaloon formation near..... 47
  stratified gravels near, plate showing.... 70
  terraces on, figure showing.............. 70
Knik River, graywackes and slates of........ 16-17
Knowlton, F. H., on Tertiary fossils...... 42,51-52

L.

Limestone, Lower Cretaceous, distribution, age, and character of............ 32-33
Lower Cretaceous rocks, character and distribution of............... 22-23,32-33
Lower Jurassic rocks, character and distribution of.................... 17-19,29-31

M.

Martin, G. C., work of....................... 10
Matanuska River, coal bed on................. 77
  gravel beds near, plate showing.......... 70
  porphyry sill near, plate showing........ 56
  section of Chickaloon formation on....... 49
Matanuska Valley, location of................ 9
  location of, map showing................. 10
  north wall of, plate showing............. 10
  topographic and geologic maps of.... In pocket
  stratigraphic sequence in................ 15
Metals, occurrence of........................ 96
Mica schists, character and distribution of... 15
Middle Jurassic rocks, character and distribution of......................... 20-22
Mineral resources, detailed account of........ 75-95
Mine sites, conditions affecting choice of..... 92-93
Moose Creek, coal beds on.................... 87-88
  gravel beds near, plate showing.......... 70
  section of Chickaloon formation near..... 49
  terraces on, figure showing.............. 70
Morainic deposits, character and distribution of......................... 68-69

N.

Navigation, conditions affecting............ 13

P.

Porphyry sills, plate showing............... 56
Precipitation, data on...................... 12

Q. Page.

Quaternary deposits, character and distribution of.................... 25-26,67-72

R.

Railroads, surveys for....................... 13
Red Mountain, coal bed on.................... 82
Routes, data on.............................. 13

S.

Shale, Tertiary, character, and distribution of. 39-42
Sheep Valley, granite and arkose in, plates showing.......................... 28
Slates, of Knik River, character of......... 16-17
Stanton, T. W., on Jurassic fossils.. 20,22,30,31-32
  on Tertiary fossils...................... 82
  on Upper Cretaceous fossils.............. 36-39
Structure, general features of............... 72-75
Structure sections, plates showing........... 72
Supplies, availability of.................... 93
Surveys, account of.......................... 9-10

T.

Talkeetna Mountains, plate showing........ 10
Temperature, data on........................ 12
Terrace gravels, character and distribution of. 69-
  on Moose Creek and Kings River, diagram showing..........................
Tertiary fossils, identifications of.............
Tertiary intrusive rocks, character and distribution of......................... 54
Tertiary lavas, Eska conglomerate overlying, plate showing....................
Tertiary rocks, character and distribution of.......................... 24-25,
Trachytic rocks, character and distribution of
Trails, character of.........................
Tuff, Jurassic, distribution, age, and character of..........................
Tuffs, Tertiary, character and distribution of.

U.

Upper Cretaceous rocks, character and distribution of....................
Upper Jurassic rocks, character and distribution of..........................

V.

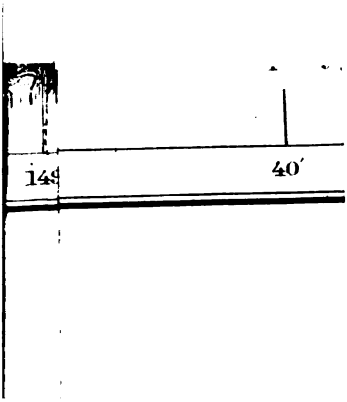
Vegetation, character of..................
Volcanic breccia, distribution, character, age of..........................

W.

Water, underground, effect of...............
Wishbone Hill, Eska conglomerate at, showing..........................

Y.

Young Creek, coal beds on....................
  fault near, plate showing...................
  porphyry sill near, plate showing........
  relation of diorite porphyries to sediments on, sections showing.............


14
40′

[illegible]